OCTOBER 27, 1994

EDN®

THE DESIGN MAGAZINE OF THE ELECTRONICS INDUSTRY

13 DEC 95

NEW PRODUCT INTROS

ELPDs double gate density pg 15

New DSOs work 10 times as hard as predecessors pg 15

New LCDs reap benefits of active addressing pg 55

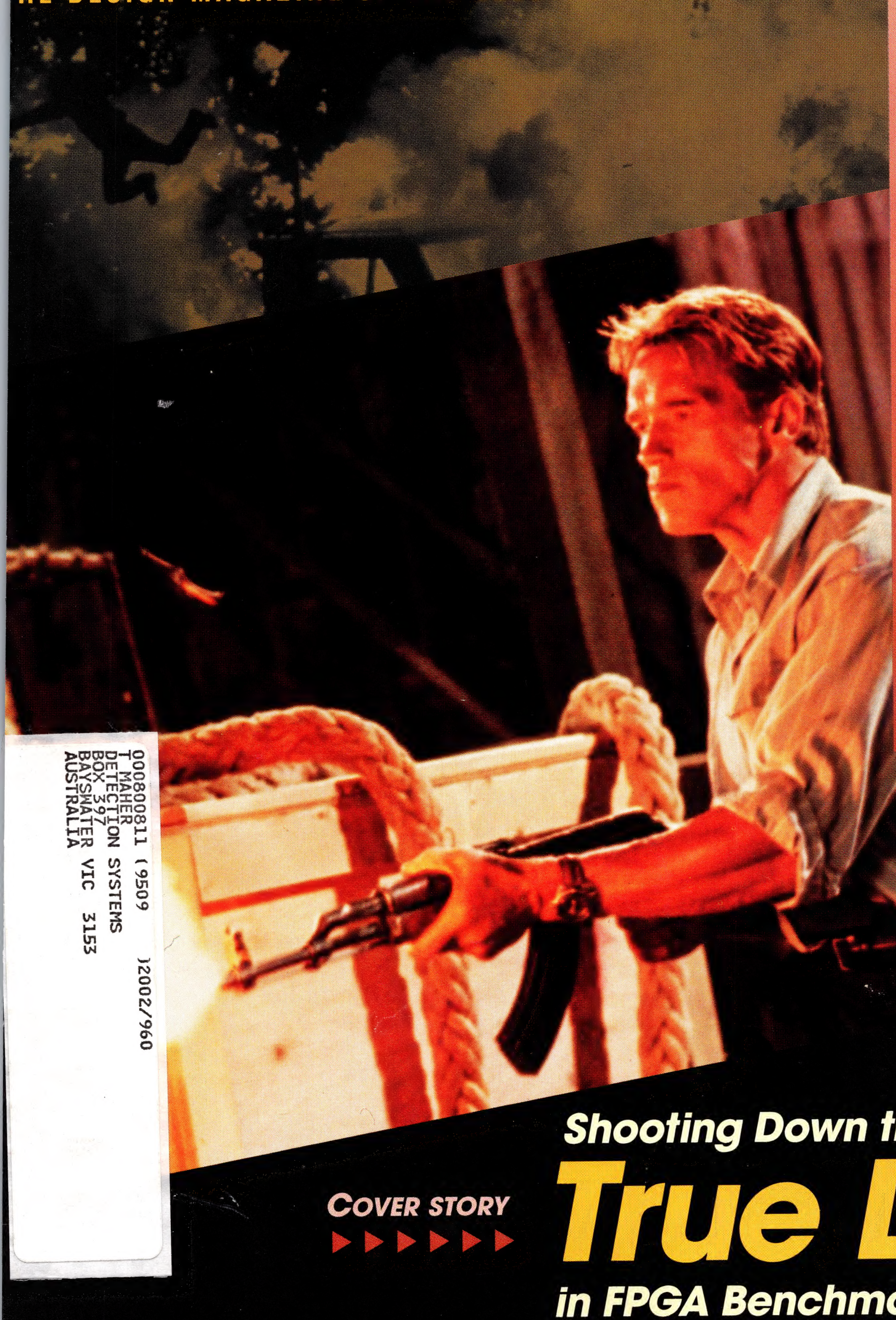
Compression techniques conserve electromagnetic-spectrum space pg 63

Design Ideas pg 83

Maximize dynamic range in CCD-based imaging systems pg 101

BiCMOS-based 3.3V PLDs pg 117

DILBERT® pg 16



000800811 (9509)2002/960
T MAHER
DETECTION SYSTEMS
BOX 397
BAYSWATER VIC 3153
AUSTRALIA

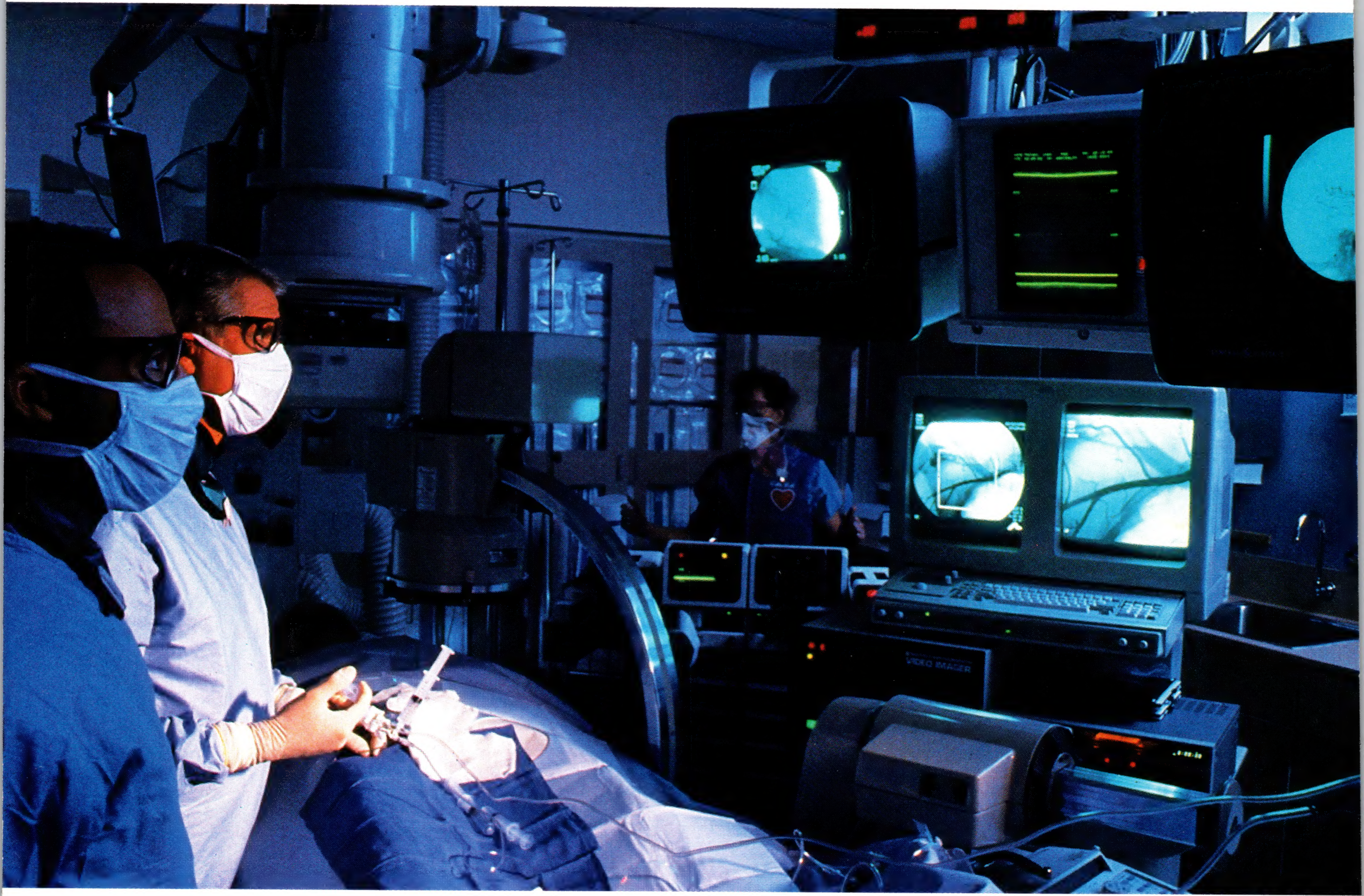
COVER STORY ▶▶▶▶▶▶

Shooting Down the True Lies in FPGA Benchmarking

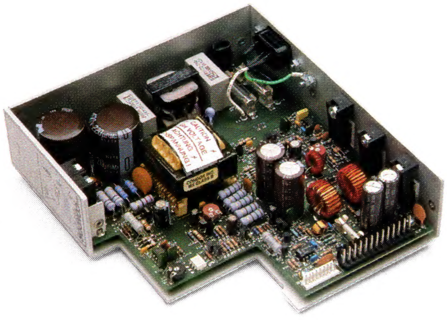
pg 38

A CAHNERS PUBLICATION

When reliability counts, we have the power supplies you need.



Condor's medical D.C. power supplies meet the world's toughest safety standards.



Our medical switchers and linears meet every international safety requirement, including IEC601, VDE0750, UL544 CSA1402-3 and CSA22.2 No. 125. Only Condor combines full agency approvals with so many great features, including:

- 38 single- and multiple-output linears
- 44 multiple-output switchers
- More than 200 modified and custom medical designs (with all agency approvals)
- Leakage current less than 60μA (switchers) or 8μA (linears)
- Meet FCC20870, Class B and VDE0871, Class B with patented low-leakage filter
- Worldwide AC input ranges
- Industry-standard packages
- 100% burn-in/2-year warranty (switchers)
- 100% burn-in/3-year warranty (linears)
- Tested I.C.'s and 105 °C capacitors used throughout

Condor also offers complete design and manufacturing capabilities for custom medical units, with 100% success in obtaining required worldwide agency approvals. For safety, quality and reliability, look to the world leader in medical D.C. power supplies—Condor!

WORLD CLASS RELIABILITY

CONDOR

Condor D.C. Power Supplies, Inc. • 2311 Statham Parkway, Oxnard, CA 93033 • (805) 486-4565 • 1-800-235-5929 (outside CA)
FAX (805) 487-8911 • Send for our catalog, or see us in EEM.

CIRCLE NO. 26

When Time Is Money...

Call, write or fax for your FREE CATALOG today!

Rated #1 for . . .

- **Availability of Product!**
- **On-Time Delivery!**
- **Overall Performance!**

Digi-Key® CORPORATION

Quality Electronic Components, Superior Service

1-800-344-4539

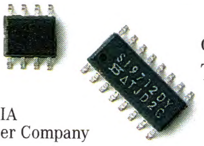
701 Brooks Ave. South, Thief River Falls, MN 56701
Fax: 218-681-3380

CIRCLE NO. 29

New Siliconix PCMCIA power switches. Until now, current spikes were a real nightmare.

Our new integrated power switches give you programmable ramp times from 200 µs to 10 ms V_{CC} for a safer power up sequence.

Part No.	On-Resistance				V_{CC} Ramp Typical
	$12\ V_{PP}$	$V_{PP}=V_{CC}$	$5\ V_{CC}$	$3.3\ V_{CC}$	
Si9710CY	0.2Ω	0.3Ω	0.2Ω	0.15Ω	0.2 µs
Si9711CY	0.2Ω	0.3Ω	0.2Ω	0.15Ω	250 µs
Si9712DY	0.12Ω	0.15Ω	0.07Ω	0.06Ω	2 ms
Si9706DY	V_{CC} only		0.08Ω	0.07Ω	2 ms
Si9707DY	V_{CC} only		0.08Ω	0.07Ω	2 ms



PC Card
PCMCIA
Member Company

One of the scariest parts about designing battery-operated portable products is current spikes. Now, thanks to our new family of power interface switches, you can eliminate potentially damaging spikes during the power up sequence. And that's not all.

The Si9712DY switches save you board space because they come in a 16-pin SOIC narrow-body, surface-mount package. You won't need all those other external discretes, either. They also interface with the most popular logic controllers, and have a rugged 2-A rating with variable ramp times. Plus, the Si9712DY guarantees on-resistance lower than 70 mΩ, giving you better tolerances on your system's socket voltage, typically V_{CC} ± 5%.

So if current spikes are spooking your designs, rest assured, our new switches are a dream come true. For a PCMCIA Power Switching Design Guide, call us at **1-800-554-5565, ext. 940.**

TEMIC
Siliconix, A Member of TEMIC

TEMIC is a company of AEG Daimler-Benz Industrie. 2201 Laurelwood Road, Santa Clara, CA 95054 Fax: 408-970-3995.
Members of TEMIC Semiconductors: Telefunken Semiconductors, Siliconix, Matra MHS, Dialog Semiconductor.
TEMIC International Sales: UNITED KINGDOM: 0344-485757. GERMANY: 0310 857 320. FRANCE: 130 60 70 00. ITALY: 02-332 121.
SCANDINAVIA: 08-733 0090. SINGAPORE: 65-788 6668, ext. 249. HONG KONG: 852-3789 789. JAPAN: 3-5562 3321.
©1994 Siliconix/TEMIC. All rights reserved.

GaAs SWITCHES

DC-2GHz Immediate Delivery from $2.30 (1000 qty.)

Finally! A line of SPDT absorptive, reflective and transfer switches that appeals to your technical side, and business side as well! It's Mini-Circuits GaAs switches...providing outstanding performance features such as very high isolation (up to 60dB), superfast 3nsec switching speed and excellent compatibility with surface mount soldering techniques. Additionally, the entire series is built extremely tough and is immediately available from stock with a 1 week shipment guarantee. At only $2.95 (qty.10), this top-of-the-line value is priced with your bottom line in mind! To order, call or Fax Mini-Circuits with your requirements today.

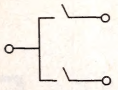
Mini-Circuits...we're redefining what VALUE is all about!

Model No.	Freq. (GHz)	Insertion Loss ① dB (max.)	1dB Comp. ① dBm (typ.)	In-Out Iso. ① dB (typ.)	Price $ea. (qty.10)
MSW-2-20 (Reflective)	DC-2.0	1.0	+24	34	2.95
MSWA-2-20 (Absorptive)	DC-2.0	1.3	+27	40	3.45
MSWT-4-20 (Transfer)	DC-2.0	1.8 TX ② 2.0 RX ③	+28 TX ② +27 RX ③	30	3.95

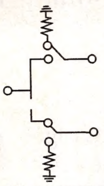
① Midband, 500-1000MHz ② Transmit ③ Receive

All Units: SOIC 8pin Package

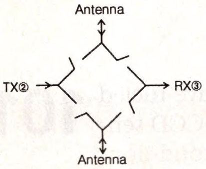
Actual Size



SPDT REFLECTIVE



SPDT ABSORPTIVE



TRANSFER

Mini-Circuits®

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661

For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM • MINI-CIRCUITS' 740- pg. HANDBOOK.

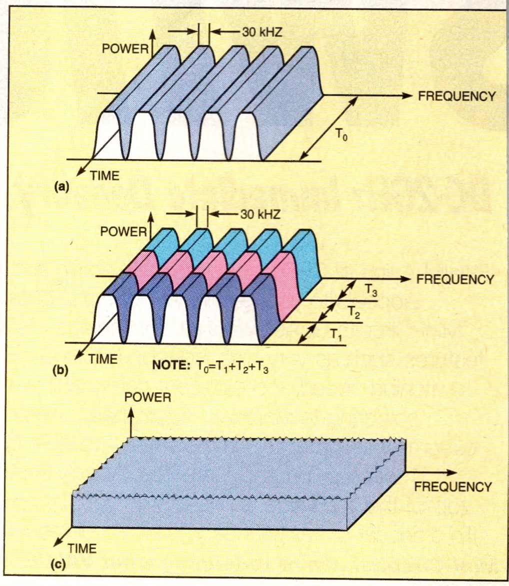
CUSTOM PRODUCT NEEDS...Let Our Experience Work For You.

CIRCLE NO. 49

EDN OCTOBER 27, 1994

A Cahners Publication/Volume 39, Number 2

Cover story: The FPGA-synthesis world is going through its own version of *True Lies*. *(Photo courtesy Twentieth Century Fox)* 38



Compression techniques 63

EDN DESIGN FEATURES

Shooting down the *True Lies* in FPGA-synthesis benchmarking
To the casual observer, benchmarking FPGA-synthesis software seems a dull and predictable step in evaluating any software package. Yet under the surface you will find more drama than in the movies.—*John Cooley, EDA Consumer Advocate* **38**

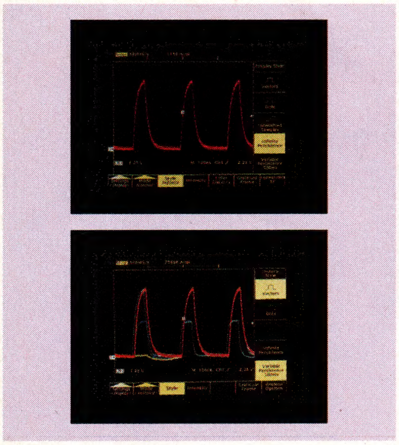
New LCDs reap benefits of active addressing
Active-matrix displays are good but expensive. Passive-matrix displays are cheap but don't perform nearly as well. New LCDs with active addressing are staking out an attractive middle ground.
—*Chris Chinnock, Technical Marketing Services* **55**

Compression techniques conserve electromagnetic-spectrum space
The overcrowded electromagnetic spectrum is continuously striving to meet ever-increasing demands. Digital enhancements to the cellular-phone infrastructure are helping to preserve some of this precious commodity.—*John Gallant, Technical Editor* **63**

Maximize dynamic range in CCD-based imaging systems
The promises of multimedia and the "paperless office" have fueled explosive growth in the electronic-imaging industry. The CCD sensor at the heart of imaging systems needs careful signal conditioning to achieve maximum performance.
—*Steve Ruscak, Analog Devices Inc* **101**

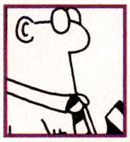
Get ready to design with new-generation, BiCMOS-based 3.3V PLDs
When designing with the coming generations of 3.3V PLDs, an understanding of the inherent characteristics of BiCMOS and pure-CMOS designs will help you optimize performance.
—*Ron Cline, Philips Semiconductors* **117**

OUT IN FRONT



DSOs' rapid updates quickly find signal flaws 15

New EPLDs double gate density 15



Dilbert 16

Analog FPGAs arrive 18

Superscalar RISC µPs scale performance heights 20

EDN DESIGN IDEAS

PLD implements fast four-phase clock generator 83
Protection feature enhances boost converter 84
Single gate synchronizes clock 84
Peltier element controls itself 86
ADC's reference improves RTD measurements 88
Variable gain control produces pure sine wave 90
Delay simulator debugs communications equipment 92

EDN DEPARTMENTS

Staff 10
Editorial 29
Signals & Noise 33
Career Opportunities 153
International Advertisers Index 155

EDN COLUMNIST

The organized bench 157

Quite simply, mess and clutter decrease productivity. Those few minutes a day spent putting things away save hours of searching. *—Jack Ganssle, Embedded-Systems Contributing Editor*

EDN PRODUCTS

Integrated Circuits 127
Test & Measurement Instruments 132
Microprocessors 135
Embedded Systems 136
Electronic Design Automation 140
Power Sources 144
Computers & Peripherals 146

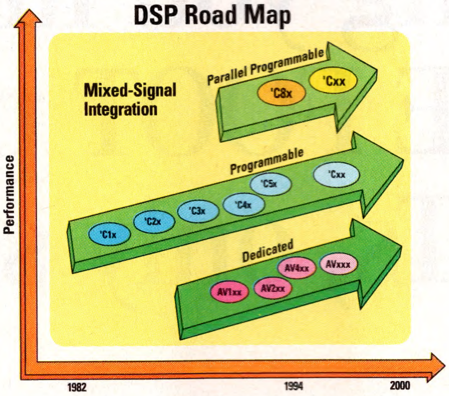
EDN® (ISSN 0012-7515, GST Reg. #123397457, C.P.C. Intl Pub Mail #0280844) is published 38 times per year, bi-weekly with one additional issue per month, by Cahners Publishing Company, A Division of Reed Publishing USA, 275 Washington Street, Newton, MA 02158-1630. Robert L. Krakoff, Chairman and Chief Executive Officer; Timothy C. O'Brien, Executive Vice President/Finance and Administration; Michael Wisner, Senior Vice President/General Manager, Boston Division; Michael Wisner, Vice President/Publishing Director. Circulation records are maintained at Cahners Publishing Company, 8773 South Ridgeline Blvd., Highlands Ranch, CO 80126-2329. Telephone (303) 470-4445. Second-class postage paid at Littleton CO 80126 and additional mailing offices. **POSTMASTER: Send address changes to EDN®, PO Box 7500, Highlands Ranch, CO 80126-7500.** EDN® copyright 1994 by Reed Publishing USA. Rates for non-qualified subscriptions, including all issues: US, $140.00 one year, $238.00 two year; Canada, $209.00 one year, $355.00 two year (includes 7% GST, GST# 123397457); Mexico, $195.00 one year, $332.00 two year; Foreign surface $245.00 one year, $417.00 two year; Foreign air expedited surcharge add $152.00 one year, $304.00 two year. Except for special issues where price changes are indicated, single copies are available for $10.00 US and $15.00 foreign. Please address all subscription mail to EDN®, 8773 South Ridgeline Blvd., Highlands Ranch, CO 80126-2329. EDN® is a registered trademark of Reed Properties Inc., used under license.

(Printed in USA)

Thanks to TI, diving into a DSP-based solution is easier than you think.

Today, digital signal processors are being designed into more of tomorrow's breakthrough products for a competitive edge. And the DSPs that are in more designs are those made by Texas Instruments — the TMS320 family.

Ten years long, fifteen thousand strong. Experience. It comes from more than ten years of helping designers extend their reach to create more advanced products with DSPs. And with a track record of supporting 15,000 customer products from various markets, we understand what you're looking for in a DSP supplier.



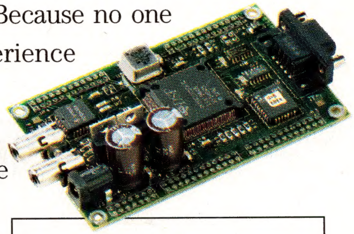
From $3 to 2 BOPS, the TMS320 family has your solution. Technology. No other DSP supplier has the breadth of price/performance solutions that get you to market faster. With a better product.

We have the selection you need. From our dedicated solutions, to our customizable, application-specific or general-purpose fixed- and floating-point programmable devices, to our 2 billion-operations-per-second parallel programmable 'C80 MVP. You'll also find a suite of mixed-signal products to complete your DSP design solution.

And no one has more worldwide DSP manufacturing capability. So, whatever you're working on today, or thinking about for tomorrow, think of TI as the one to help.

Development support how you need it. When you need it. At TI, we provide you with the most highly acclaimed DSP support program. Including off-the-shelf, world-class development tools, a hotline staffed by DSP experts, a 24-hour bulletin board, real-world application notes, DSP-design textbooks and the industry's largest network of third-party developers, including the TMS320 Software Co-op.

With our DSP information, it's easy to dive right in. No one makes it easier to design with DSPs than TI. Because no one else has the experience and the technology, as well as the support. And no one else has the power of Total Integration.™ For more information, simply call **1-800-477-8924, ext. 3651.**



For only $99, you can get the TI DSP Starter Kit. It offers you a low-cost, easy-to-use tool for initial understanding of TI TMS320 DSPs. And includes board, assembler and debugger software, sample programs and documentation. Simply call your distributor.*

EXTENDING YOUR REACH™

TEXAS INSTRUMENTS

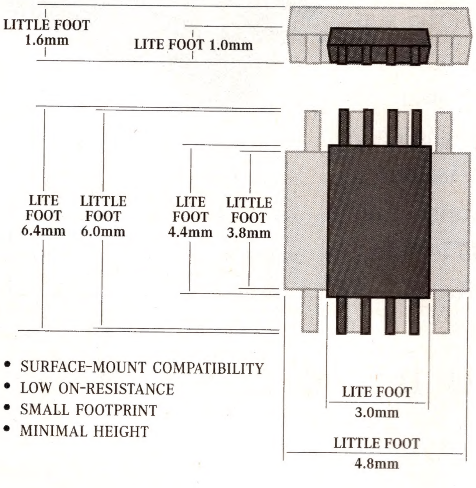
CIRCLE NO. 88

* Suggested retail.

© 1994 TI

00-8718

Introducing LITE FOOT. Everything you like about LITTLE FOOT power MOSFETs, only smaller.



- SURFACE-MOUNT COMPATIBILITY
- LOW ON-RESISTANCE
- SMALL FOOTPRINT
- MINIMAL HEIGHT

LITE FOOT™ is about half the size of LITTLE FOOT®, but delivers the same big benefits for space-sensitive and/or battery-operated applications.

Siliconix, the pioneer in 8-lead SOIC power MOSFETs, has redefined the performance of ultra-miniature, surface-mount power. The result is a new family of n-channel and p-channel devices that delivers on-resistance as low as 50 mΩ. Further, LITE FOOT features TSSOP surface-mount compatibility, and offers gate drive voltages as low as 2.7 V and currents as high as 4.2 A.

In short, LITE FOOT is the smallest discrete power MOSFET in the world. It occupies only 6.4 x 3.0 millimeters of board space. And at a remarkable 1.1 mm high, it's the first vertical power

LITE FOOT Part No.	TYPE	V_{DS} (V)	$r_{DS(on)}$ (mΩ)*	I_D (A)
Si6436DQ	Single N-Ch	30	50	4.2
Si6956DQ	Dual N-Ch	20	100	2.5
Si6433DQ	Single P-Ch	-12	75	3.5
Si6447DQ	Single P-Ch	-20	100	3.0
Si6953DQ	Dual P-Ch	-20	200	1.7
Si6542DQ	Complementary N-Ch P-Ch	 20 -20	 100 200	 2.5 1.7

* On-Resistance shown at V_{GS} = 10 V, except Si6433DQ shown at V_{GS} = 4.5 V

MOSFET thin enough to fit into any standard PCMCIA card. Even double-sided circuit boards are a snap.

What's more, LITE FOOT's mini package maximizes power dissipation, too — over 1.5 W in a tiny 8-lead TSSOP. But best of all, you don't need an external heat sink other than the PC board itself.

So if your designs keep shrinking, but your power management needs keep getting bigger, LITE FOOT is the solution.

Contact your local TEMIC sales office, or call **1-800-554-5565, ext. 931** for a LITE FOOT design guide.

Siliconix

A Member of the TEMIC Group

2201 Laurelwood Road, Santa Clara, CA 95054 Fax: 408-970-3995
Members of the TEMIC Semiconductor Division: Telefunken Semiconductors, Siliconix, Matra MHS, Dialog Semiconductor
TEMIC International Sales: UNIITED KINGDOM: 0344-485757. GERMANY: 0130 857 320. FRANCE: 1 30 60 70 00. ITALY: 02-332 121.
SCANDINAVIA: 08-733 0090. SINGAPORE: 65-788 6668, ext. 249. HONG KONG: 852-3789 789. JAPAN: 3-5562 3321.

LITTLE FOOT is a registered trademark and LITE FOOT is a trademark of Siliconix. ©1994 Siliconix. All rights reserved.

EDN

Home Office: 275 Washington St, Newton, MA 02158. EDN Bulletin Board: (617) 558-4241; MCI: EDNBOS; fax (617) 558-4470; phone (617) 964-3030.

PUBLISHER **Jeffrey Patterson (617) 558-4454**

EDN'S EDITORIAL OFFICES

EDITOR-IN-CHIEF	Steven H Leibson (617) 558-4214; MCI: ednleibson
EXECUTIVE EDITOR	Gary Legg (617) 558-4404; MCI: ednlegg
MANAGING EDITOR	Joan Lynch (617) 558-4215; MCI: ednmorrow

SENIOR TECHNICAL EDITORS	Charles Small (617) 558-4556; MCI: ednsmall Dan Strassberg (617) 558-4205 MCI: ednstrassberg Brian Kerridge 22 Mill Rd, Loddon, Norwich, NR14 6DR, UK; (508) 528435; fax: (508) 528430; MCI: ednkerridge Bill Travis (617) 558-4471; fax: (617) 558-4471; MCI: edntravis
TECHNICAL EDITORS	John Gallant (617) 558-4666; MCI: edngallant Richard Quinnell (408) 685-8028 (phone and fax); MCI: ednquinnell Anne Watson Swager (215) 645-0544 (phone and fax); MCI: ednswager Markus Levy (916) 939-1642; fax: (916) 939-1650; MCI: ednlevy
SPECIAL-PROJECTS EDITOR	Doug Conner (805) 461-9669; fax (805) 461-9640; MCI: edndconner
SENIOR ASSOCIATE EDITORS	Frances T Granville (617) 558-4344 James P Leonard (617) 558-4324
ASSOCIATE EDITOR	Anne Coyle (617) 558-4333
CONTRIBUTING TECHNICAL EDITORS	Robert Pease, Jack Ganssle, David Brubaker, Don Powers

EDITORIAL AND ART PRODUCTION	Diane Malone, Manager (617) 558-4303 Kenneth Racicot, Senior Art Director (617) 558-4708 Chinsoo Chung, Associate Art Director (617) 558-4446 Patricia Shaughnessy, Production Editor (617) 558-4206
ASSISTANT TO THE EDITOR-IN-CHIEF	Kathy Leonard (617) 558-4405 MCI: ednleonard
EDITORIAL SERVICES	Helen Benedict (617) 558-4681
ADVERTISING PRODUCTION	Andrew Jantz, Group Manager (617) 558-4372 Karen Banks, Manager (617) 558-4441 Alice Dorsey, Associate (617) 558-4601
DIRECTOR OF CREATIVE SERVICES	Norm Graf (617) 558-4293
EDN ASIA	Mike Markowitz, Editor 19F, 8 Commercial Tower, 8 Sun Yip St, Chai Wan, Hong Kong. phone (011) (852) 965 1555; fax: (011) (852) 976-0706
EDN PRODUCTS	301 Gibraltar Dr, Box 650 Morris Plains, NJ 07950 Phone (201) 292-5100; fax (201) 292-0783

EDN'S BUSINESS AND ADVERTISING OFFICES

ADVERTISING SALES DIRECTOR	Paul Rothkopf (617) 558-4651
MARKETING/BUSINESS DIRECTOR	Deborah Virtue (617) 558-4779
CUSTOM PUBLISHING SERVICES	Patricia Tyler, Director (617) 558-4526
ASSISTANT TO PUBLISHER	Maria McGrath (617) 558-4346
CONTRACTS	Muriel Murphy (617) 558-4451 Julie Waelde (617) 558-4250
CIRCULATION	Debbie Barela (303) 470-4000

NEW ENGLAND
CHRIS PLATT
(617) 964-3730
fax: (617) 332-7128

NEW YORK/NEW JERSEY/ MID/SOUTH ATLANTIC
DIANE DRISCOLL
(203) 326-5161
fax: (203) 326-5160

IL/IN/KY/OH/TN/ TX/OK/FL/SC
JOANN CANNON
(708) 635-8800
fax: (708) 635-0929

IL/MI/MN/NE/IA/KS/ND/SD/WI/ MO/AL/AR/GA/MS/CANADA
JACK JOHNSON
(708) 635-8800
fax: (708) 390-2815

ARIZONA
DONNIE JONES ADAMS
(408) 243-8838
fax: (408) 345-4400

ORANGE/RIVERSIDE/SAN DIEGO COUNTIES/LOS ANGELES/
Southern CA/NV
SUSAN N GREEN
(714) 851-9422
fax: (714) 752-6867

COLORADO/ WASHINGTON/OREGON
ROGER GAW
(408) 243-8838
fax: (408) 345-4400

NORTHERN CA/SILICON VALLEY
DONNIE JONES ADAMS
BETTINA MCGOWAN
ROGER GAW
(408) 243-8838
fax: (408) 345-4400

PRODUCT MART
JOANNE DORIAN
(212) 463-6415
fax: (212) 463-6404

UK
JOHN WADDELL
(011) 44 81 312 4696
fax: (011) 44 81 312 1078

NORWAY/SWEDEN/FINLAND
ROLAND NIHLMAR
LARS GRUNBERGER
(011) 46 8616 0760
fax: (011) 46 8616 0777

DENMARK
AASE KISBORG
(011) 45 33 14 9888
fax: (011) 45 33 14 9288

NETHERLANDS/BELGIUM/ GERMANY ZIP CODES 0-5
ALBERT TICHELER
(011) 31 40 41 37 27
fax: (011) 31 40 42 0430

GERMANY ZIP CODES 6-7
ERHARDT EISENACHER
(02 28) 65 00 13
fax: (02 28) 65 00 76

GERMANY ZIP CODES 8-9
MARGARETHE MUNCHMEIER
(011) 49 89 222 015
fax: (011) 49 89 299 160

SPAIN
LUIS GINER
(011) 343 894 43 26
fax: (011) 343 894 88 37

AUSTRIA
SVEN KOLLENSPERGER
(011) 43 732 79 34 55
fax: (011) 43 732 79 34 58

ISRAEL
ASA TALBAR
(011) 972 35 223 621
fax: (011) 972 35 242 177

ITALY
ROBERTO LAURERI
(011) 39 2 236 2500
fax: (011) 39 2 236 4411

SWITZERLAND
ROSWITHA N BRIAND
(011) 41 1261 4690
fax: (011) 41 1251 4542

FRANCE
ALAIN FAURE
(011) 331 4629 4629
fax: (011) 331 4093 0337

HONG KONG
ADONIS MAK
(011) 852 965 1555
fax: (011) 852 976 0706

JAPAN
KAORU HARA
(011) 813 3389 1822
fax: (011) 813 3389 1761

KOREA
JEONG-GWON SEO
(011) 82 2752 4392
fax: (011) 82 2752 4394

SINGAPORE/MALAYSIA
HOO SIEW SAI
(011) 65 738 0122
fax: (011) 65 738 2108

TAIWAN
PARSON LEE
JOHN SHIH
(011) 886 2711 4833
fax: (011) 886 2741 5110

AUSTRALIA
ALEXANDRA HARRIS-PEARSON
(011) 612 299 5677
fax: (011) 612 299 6178

TURKEY
CENGIZ EREN
(011) 90 216 345 3473
fax: (011) 90 216 346 2464

INSIDE SALES
LISA BARRIERE
(617) 558-4361
fax: (617) 558-4328

INFO CARDS/ LITERATURE LINK
MELISSA BACHMAN
(617) 558-4282
fax: (617) 558-4328

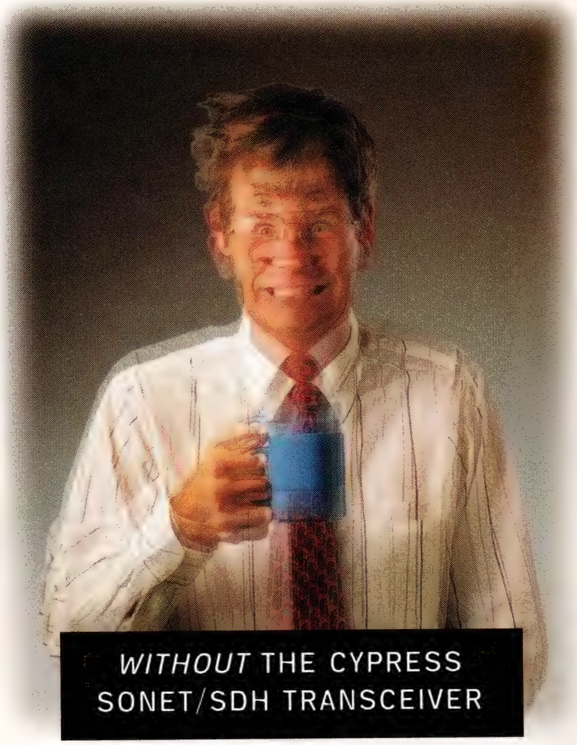
RECRUITMENT
PATRICIA KENNEFICK
(617) 558-4488
(617) 630-3925

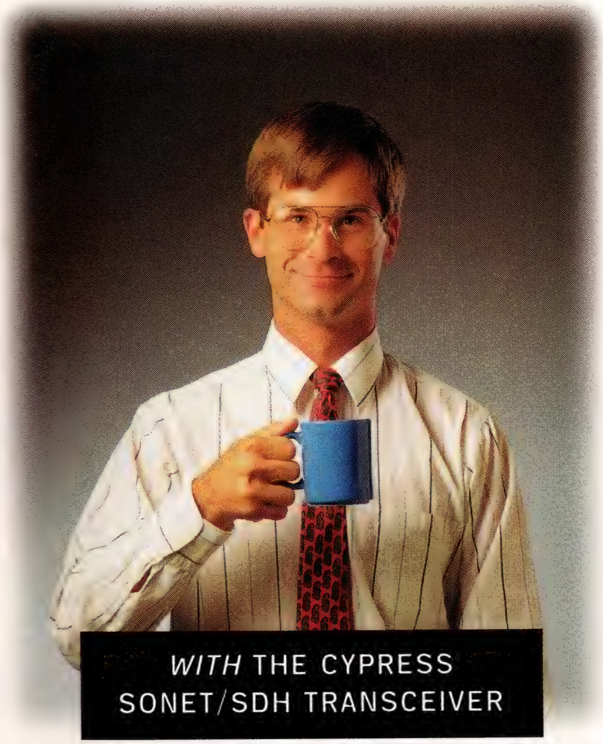
CAHNERS MAGAZINE DIVISION
ROBERT KRAKOFF
President, CEO
Cahners Publishing

CAHNERS MAGAZINE DIVISION
MICHAEL WISNER
Senior VP/General Manager
Boston Division

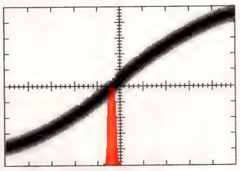
CAHNERS MAGAZINE DIVISION
TOM DELLAMARIA
Senior VP/
Production & Manufacturing

DELICIOUS ATM, WITHOUT THE JITTERS.


WITHOUT THE CYPRESS SONET/SDH TRANSCEIVER

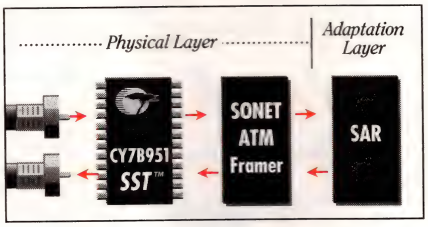

WITH THE CYPRESS SONET/SDH TRANSCEIVER

Here's a wake-up call for anyone designing-in ATM functionality: the CY7B951 SST™ (SONET Serial Transceiver) clock recovery chip from Cypress. With its minuscule jitter of just 10 ps, the SST is as close as you can get to guaranteed flawless performance in your ATM environment.


Industry's Lowest Jitter

In fact, it is the only solution to support both major ATM application frequencies (51.8 OC-1 and 155.52 MHz OC-3.)

Thanks to its integrated transmit and receive phase lock loops, the SST lets you use a low-cost 19.44 MHz oscillator. The SST also performs wonders for board space by eliminating the need for external filter components.



By using advanced BiCMOS technology, the SST consumes a miserly 50 mA, for power savings of up to 50% over competitive devices. And its loop-back testing capabilities enable in-system diagnostics.

So don't let the stringent jitter requirements of ATM get on your nerves. Start off your next design day with the SST from Cypress, the high-speed leader. It'll open your eyes.

For your free sample certificate and design kit. Call 1-800-858-1810, Dept. C413

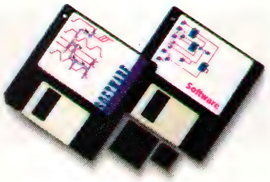
CYPRESS

*In Europe, fax requests to the above Dept. at (32) 2-652-1504 or call (32) 2-652-0270. In Asia, fax to the above Dept. at 1 (415) 940-4337.© 1994 Cypress Semiconductor, 3901 North First Street, San Jose, CA 95134 Phone 1-408-943-2600.

MACH now features workstation support from Cadence, Data I/O, Mentor Graphics, MicroSim, MINC, Synopsys, and Viewlogic.

Nanoseconds Alo
How AMD Has Impro

The New MACH® Family Gives You 7.5ns Speeds, Plus The Design Tools You Need To Get To Market Faster.



The new MACH family members feature speeds up to 7.5ns, while our new software tools include schematic design entry and timing simulation capabilities.

You can never be too fast.

Or too well equipped, for that matter. And the new MACH CPLDs give you both: The speed you need for the critical path — up to 7.5ns. Plus a whole new set of design tools you'll need along the way.

There's nothing faster than the new members of our MACH family. Our 1800-gate MACH 210A-7 clocks-in at 7.5ns, while our 3600-gate MACH 230-10 reaches 10ns. Now that's fast.

And you'll bring your product to market in record time with AMD's new software offerings. Now you can get your favorite design tools — including MicroSim, Data I/O® and Viewlogic™ — directly from AMD.®

One AMD Place, P.O. Box 3453, Sunnyvale, CA 94088. © 1994 Advanced Micro Devices, Inc. FusionPLD is a service mark and MACH, AMD, and the AMD logo are registered trademarks of Advanced Micro Devices, Inc. Other product or brand names mentioned are property of their respective holders.

ne Can't Measure
ved The MACH Family.

You get the right tools, right away.

If you need additional design support, you can always rely on our FusionPLD℠ partners, a team of vendors ready and waiting to give you the support you need when speed is of the essence.

What's more, AMD delivers both JTAG testing and 5-Volt in-circuit programming. So you have the flexibility to test, program, and reconfigure your designs right on the board. And both capabilities are an integral part of our free in-circuit programming kit.

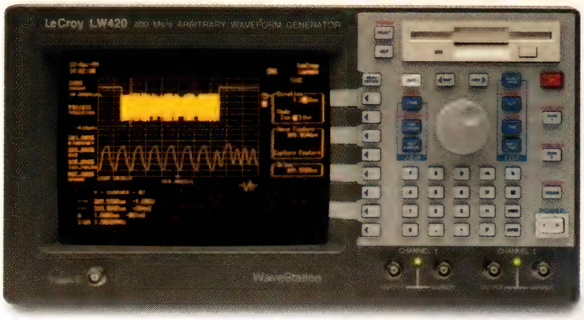
So call AMD today for more information on the entire high-speed MACH family, design tools, and our free 5-Volt in-circuit programming kit. Because with AMD behind you, you'll finish faster every time.

800-222-9323

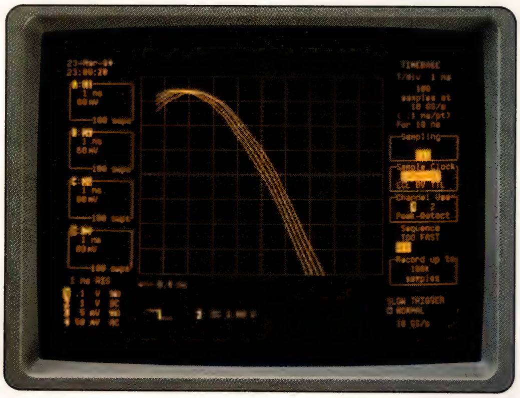
Ask for our free programming kit 19Q.

Advanced Micro Devices

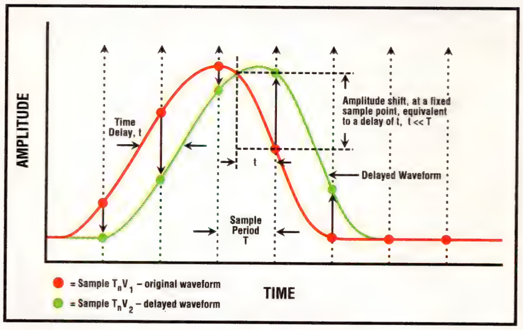
LeCroy
Arbitrary
Waveform
Generators



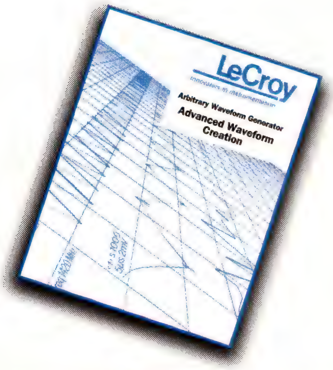
Live
Manipulation
of all Waveform
Features



On-the-Fly
Edge Placement
to 100ps
Resolution


AMPLITUDE
Time Delay, t
Amplitude shift, at a fixed sample point, equivalent to a delay of t, t << T
t
Delayed Waveform
Sample Period T
● = Sample T_nV_1 – original waveform
● = Sample T_nV_2 – delayed waveform
TIME

Sub-sample waveform control is the secret to 100psec waveform feature placement. But ONLY LeCroy uses a unique rapid recalculation algorithm to shift waveform features in direct response to front panel controls.


LeCroy
Innovators in Instrumentation
Arbitrary Waveform Generator
Advanced Waveform Creation

Call for FREE Technical Guide
to Arbitrary Waveform Generators

800-4-LeCroy

1-800-453-2769
700 Chestnut Ridge Road, Chestnut Ridge, NY 10977

LeCroy
Innovators in Instrumentation

CIRCLE NO. 47

New EPLDs double gate density

Altera's MAX 9000 family of PLDs offers more than double the density of other available erasable PLDs (EPLDs). The family comprises four members ranging in density from 320 to 560 macrocells (6000 to 12,000 usable gates). Built on a 0.65-μm process, the family operates at 80 MHz. The MAX 9000 extends the density of the company's MAX 7000 PLDs and offers in-system programming (ISP), 3.3/5V I/Os, and JTAG capabilities.

The basic building block in the architecture is a macrocell that comprises product terms and a configurable flip-flop. In traditional macrocells, using only the product terms wastes the flip-flop. To address that problem, Altera has created a dual-output macrocell structure, which allows independent use of the flip-flop and product terms. This technique increases flip-flop utilization by 20%.

The design groups 16 macrocells into logic-array blocks (LABs) that allow implementation of large logic functions without tying up routing resources. The interconnections between LABs are through a network of continuous metal lines that traverse the device horizontally and vertically. The interconnection scheme provides a 3D structure with predictable delays.

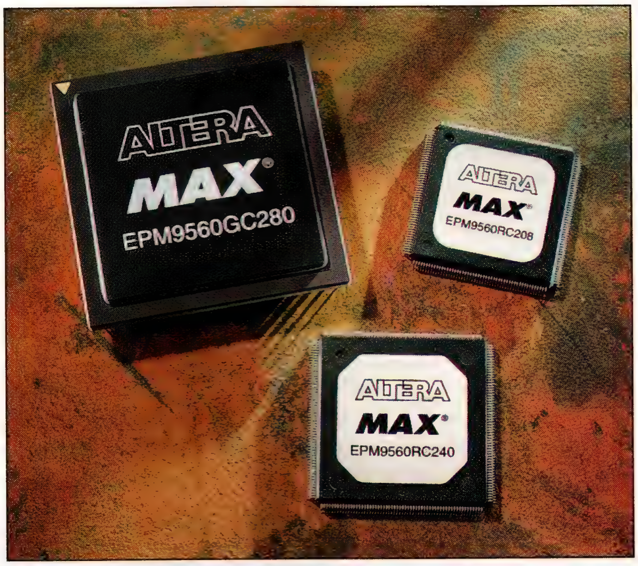
Each I/O pin in the MAX 9000 architecture contains an I/O register to improve chip-to-chip communication. In addition, all I/O pins can handle 5 or 3.3V signals and have programmable slew rates to compensate for ground-bounce effects. The MAX 9000 complies with JTAG to ease board-level testing.

ISP eases the design of engineering prototypes and manufacturing because it eliminates the handling of high-lead-count devices during programming. Designers can place ISP devices onto circuit boards using standard pick-and-place equipment. They can also program the devices while soldering them onto the pc board without the risk of lead damage or ESD. In addition, designers can change their designs any number of times without removing the device from the board.

Altera's MAX+Plus II development software for PCs and workstations supports the MAX 9000 devices. The MAX+Plus II provides seamless integration with tools from Cadence, Data I/O, Mentor Graphics, Synopsys, ViewLogic, and other EDA vendors. The first device in the family, the EPM9560 (560 macrocells, 12,000 usable gates), costs $50 (10,000) and will be available in the first quarter of next year. The second device, the EPM9320 (320 macrocells, 6000 usable gates), will be available in the second quarter and will cost $25 (10,000).

—by John Gallant

Altera Corp, San Jose, CA, (408) 894-7000. **Circle No. 419**



Altera's MAX 9000 family offers 6000 to 12,000 usable gates.

DSOs' RAPID UPDATES QUICKLY FIND SIGNAL FLAWS

Even if it takes 2G samples/sec, your digital storage oscilloscope (DSO) is most likely loafing on the job, and you're suffering the consequences of its sloth. If your company can afford a new scope, however, that situation need not continue. On Nov 1, Tektronix will announce a pair of four-channel DSOs that acquire and display up to 440,000 waveforms/sec. That rate is from 10 to several thousand times as great as that of more conventional high-performance DSOs. The improvement can mean that you'll spend seconds instead of hours looking for infrequent anomalies in high-duty-cycle waveforms. The 500-MHz-bandwidth TDS 744A ($17,750) and the 1-GHz-bandwidth TDS 784A ($34,495; $39,690 with four active probes) sample in real time at maximum rates of 2G and 4G samples/sec, respectively, in single-channel mode and offer a memory depth of 50k samples/channel (500k samples optional in single-channel mode).

Despite astronomical sampling rates, DSOs until now were unable to capture more than about 50,000 waveforms/sec. One of the fastest scopes in this regard is Tektronix's TDS 544A when it operates in the segmented-memory, sequential-acquisition mode, which Tek calls FastFrame. (Without modes like FastFrame, conventional DSOs can capture waveforms no faster than they update their displays, which usually means no faster than about 200 times/sec.)

A TDS 544A with a 50k-point memory can acquire 100 500-point waveforms before it must pause to display the captured data. At its top sweep rate—500 psec/div—the scope acquires signals for 0.5 μsec of 2 msec, a duty factor of 0.025%. Then it must update its screen, which takes as long as 30 msec.

(continued on pg 16)

Next, you have to look at what it displays; that usually takes several seconds. As a result, the duty factor for acquisitions is only a few parts/million. (The scope can overlay all of the waveforms in its segmented memory and display a single composite waveform whose color grading provides an idea of how often pixels were "illuminated.") If you're trying to observe a low-duty-factor phenomenon buried in a high-repetition-rate signal, you may have to wait a long time before the aberrant signal occurs during one of those infrequent acquisitions (**Fig 1**).

As far as acquisition duty factor goes, analog scopes have a clear edge over DSOs. But analog scopes are far from ideal for viewing infrequent signal anomalies. If you use an analog scope to look for a rare event in a high-duty-cycle signal (a metastable state, for example), you must stare into a hood for a long time at a bright trace that once in a great while exhibits a faint wiggle. The best analog scopes for this purpose are units such as Tek's 2467B, whose CRTs include electron-multiplying plates.

Tek's InstaVu feature changes this situation. InstaVu increases the DSO's acquisition duty factor to equal or exceed that of the best analog scopes. It also does away with staring into viewing hoods; infrequent events become plainly visible. Tektronix claims that the TDS 700 scopes acquire as much data in 1 sec as most other high-performance DSOs do in an hour. What makes this performance possible is a new VLSI IC that both demultiplexes the acquired samples and rasterizes them for display without requiring the scope's firmware to intervene. According to Tek, the 304-pin CMOS chip is as large and complex as an Intel Pentium µP. The Tek chip accepts bursts of data from an ADC at 1 Gbyte/sec but dissipates only 2.5W. In the new scopes, the chip does not even need a heat sink.

One of the chip's functions is to

(continued on pg 18)

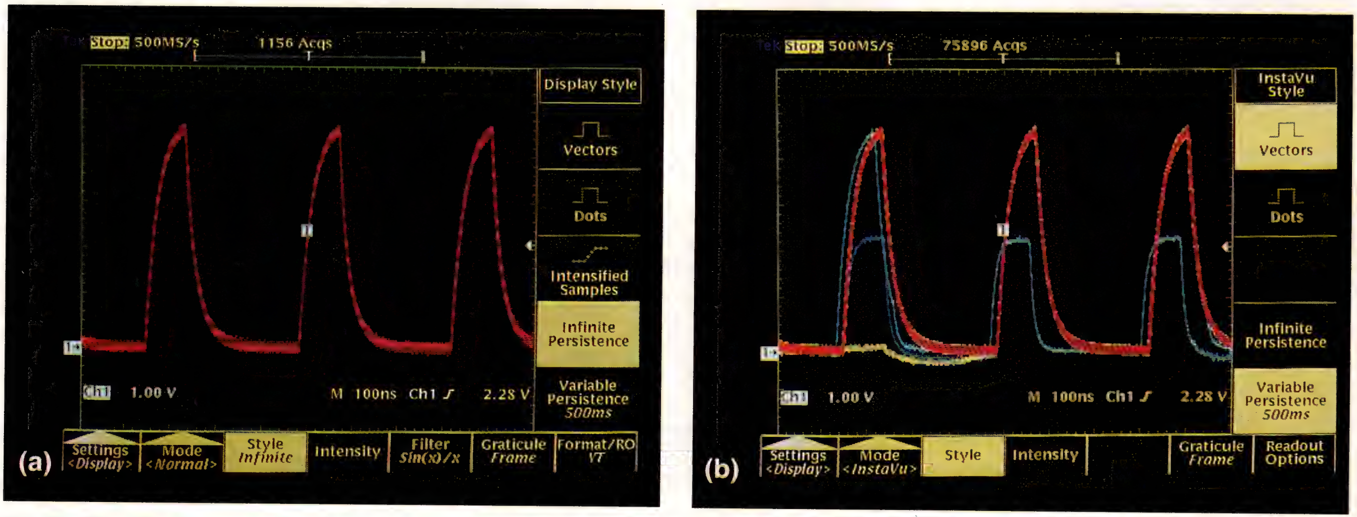
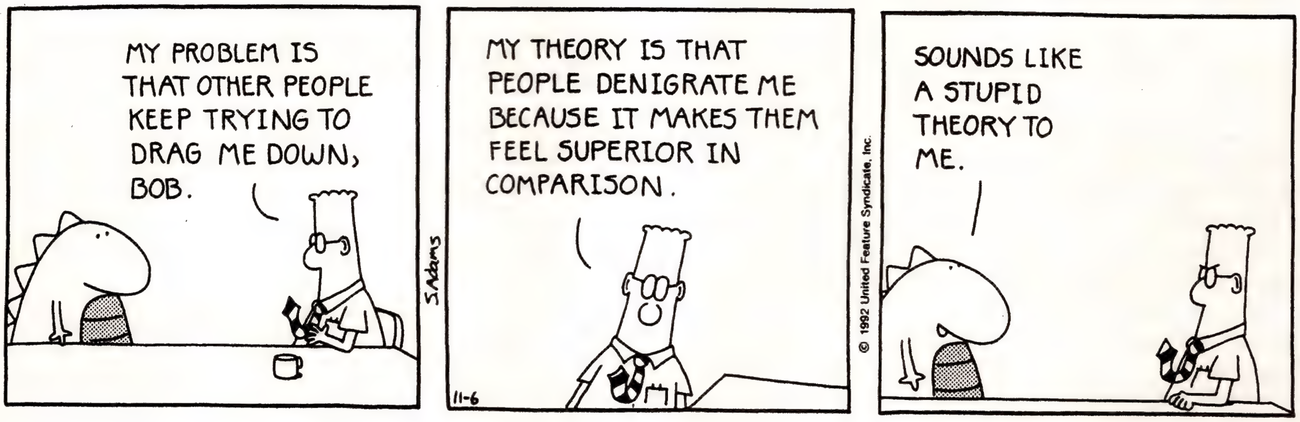


Fig 1—Waveform anomalies that you might never detect with other high-performance DSOs show up clearly on TDS 700 scopes. The same signal looks radically different when viewed with a TDS 544A without InstaVu (a) and with a TDS 784A using InstaVu (b). In this example, the difference has nothing to do with the TDS 784A's higher bandwidth. Rather, the scope without InstaVu simply doesn't retrigger often enough to catch the infrequent aberrations that show up clearly in blue throughout (b) and in yellow at (b)'s lower left. The scope spent much less time in acquiring the 75,896 waveforms that make up (b) than in capturing (a)'s 1156 waveforms.

DILBERT® by Scott Adams

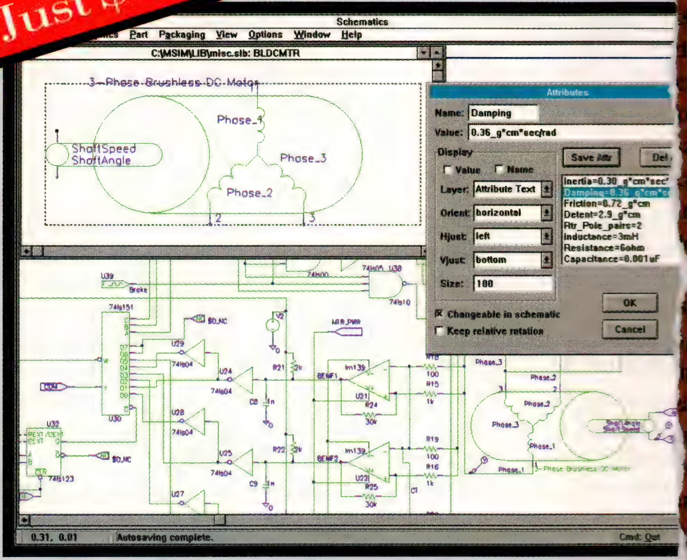
DILBERT: ©1989 United Feature Syndicate, Inc.


MY PROBLEM IS THAT OTHER PEOPLE KEEP TRYING TO DRAG ME DOWN, BOB.
MY THEORY IS THAT PEOPLE DENIGRATE ME BECAUSE IT MAKES THEM FEEL SUPERIOR IN COMPARISON.
S.Adams
11-6
© 1992 United Feature Syndicate, Inc.
SOUNDS LIKE A STUPID THEORY TO ME.

EMAIL: scottadams@aol.com

Get Half Off MicroSim Schematics for Windows

Just $475


Schematics
Part Packaging View Options Window Help
C:\MSIM\LIB\misc.slb: BLDCMTR
3-Phase Brushless DC Motor
ShaftSpeed
ShaftAngle
Phase_1
Phase_2
Phase_3
Attributes
Save Attr
Del
OK
Cancel
Cmd: Quit

Name: Damping
Value: 0.36_g*cm*sec/rad
Display
☐ Value ☐ Name
Layer: Attribute Text
Orient: horizontal
Hjust: left
Vjust: bottom
Size: 100
☒ Changeable in schematic
☐ Keep relative rotation

Inertia=0.30_g*cm*sec²
Damping=0.36_g*cm*s
Friction=0.72_g*cm
Detent=2.9_g*cm
Rtr_Pole_pairs=2
Inductance=3mH
Resistance=6ohm
Capacitance=0.001uF

0.31, 0.01 Autosaving complete.

That's right—get a full-featured Schematics package for Windows™ and Windows NT for 50% off.

MicroSim, the makers of PSpice® offers you Windows Schematics for just $475 through December 23, 1994. To get this competitive upgrade, all you have to do is call in the registration number or access code from the schematic package you're now using—and you'll save $475 from the regular price of $950.

And get the next release—including an OrCAD translator—for free.

To make this offer absolutely irresistable, we'll also give you the next release absolutely free. Among other features, the new release will include an OrCAD translator so you can move your existing OrCAD designs into MicroSim's schematic editor and use a full suite of integrated Windows tools.

And Schematics is packed with features, such as a library with symbols for over 28,000 parts.

Just because we're giving you half off doesn't mean you're getting half the features—Schematics lives up to the MicroSim name. Schematics includes a vast library of symbols for over 28,000 parts to help you create your schematic quickly. But that's not all. Schematics delivers faster 32-bit performance, support for flat and unlimited levels of hierarchy in your designs and integrated PCB interfaces to a wide range of products.

You can use MicroSim Schematics as a powerful stand-alone schematic editor or combine it with other MicroSim Design Center® products to create a circuit design system customized to your needs. Schematics is tightly integrated with other MicroSim products for Windows, Windows NT and SUN.

But hurry—don't miss out on your chance to get half off!

Don't wait too long to order Schematics from MicroSim—the company with a ten-year history of offering high-quality EDA products at prices far below competitors. Call MicroSim today for more information, or to place your order.

ce
anced
g simulation

s are
ou need,
PSpice is
olution.
ce sup-
s and signifi-
ly extends
apabilities of
eley SPICE.
atile model-
apabilities,
ding extra
els like lossy
oupled
mission
, provide
rate charac-
ation of your
it's compo-
. Model
ries contain-
ver 7,400
ican,
pean, and
ese off-the-
analog
es can be
augmented
semiconduc-
evice models
ed automati-
from data
informa-
n addition,
ce comes
Monte Carlo
ensitivity/
-case analy-
nalog behav-
model-
timulus

products in the MicroSim Design Center. Schematics is tightly integrated with products for: analog, digital and mixed A/D simulation; programmable logic synthesis, signal integrity analysis, analog performance optimization, filter design and more.

MicroSim Schematics for Windows

The Schematics product from MicroSim combines a richer feature set than most schematic packages, with an ease of use that busy designers seem to appreciate. A short list of outstanding features includes:

·*Easy-to-use interface.* The standard Windows user interface allows editing tasks to be accomplished with a minimum of menu commands. The multi-window interface allows viewing and editing of different pages or different levels of a hierarchical design at the same time.

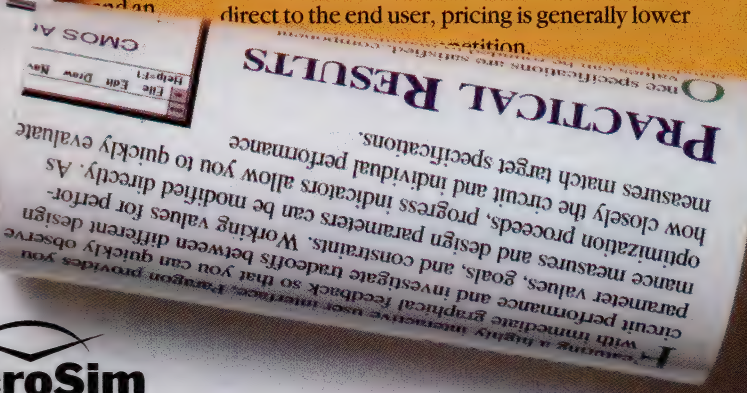
·*Fast 32-bit performance.* Schematics offers faster netlisting, schematics loading, symbol loading and faster graphics.

·*Support for both flat and hierarchical designs.* Creating a hierarchical block is as easy as placing a block and double-clicking to push into the sub-schematic it represents. Schematics can also automatically create a symbol for a sub-schematic so that it can be easily reused.

·*Integrated symbol editor.* Schematics allows the user to view, modify, or create symbols while editing the schematic – and it comes with a large library of symbols for over 28,000 parts already defined.

·*Interfaces to external board layout packages.* Schematics can produce a CADSTAR, PADS, P-CAD, Protel, SCICARDS, Tango or EDIF 2 0 0 layout netlist from a completed circuit drawing due to integrated interfaces. It also includes backward ECO support.

With this impressive list of features, it seems the MicroSim Schematics product would be costlier than most. A comparison shows the opposite to be true. Because MicroSim sells direct to the end user, pricing is generally lower



MicroSim

20 Fairbanks, Irvine, CA 92718, USA (714) 770-3022
(800) 245-3099 FAX: (714) 455-0554 BBS: (714) 830-1550

Design Center and PSpice are registered trademarks of MicroSim Corporation. All other trademarks are the property of their respective owners.

• Circle No. 150 for PC • Circle No. 152 for Workstation convert a sequence of waveforms into pixels and transmit the pixels to the (full-color) display subsystem. If the chip performed this function after each sweep, at 440,000 waveforms/sec, the data rate would become so high (over 200 Mbytes/sec—on a sustained basis) that moving the data using available technology would be difficult or impossible. Instead, the chip accumulates a series of acquisitions, converts them into pixels, and at each screen refresh, transmits a bit map of the screen that represents hundreds or thousands of sweeps. This approach keeps the data rate below 1 Mbyte/sec.

One of the beauties of InstaVu is that it recognizes how scope users work and how experience with analog scopes affects users' expectations of scope performance. Invoking InstaVu is a snap; just push one button. Invoking FastFrame requires many more steps, and that technique does not work as well for picking low-duty-cycle anomalies from a large set of normal waveforms. Not only does FastFrame result in a lower peak-duty factor, but in that mode the average duty factor drops further when the scope stops acquiring data so it can display the composite of a series of acquisitions.

Although InstaVu is the most important of the TDS 700 series' new features, it is not the only noteworthy one. The TDS 744A, which Tek sees eventually replacing the TDS 544A, acquires 500M samples/sec in real time on four channels, 1G on two, and 2G on one. These rates are twice those of the TDS 544A, which costs only about 5% less and offers memory depths that are under one-third of the TDS 744A's standard value and one-tenth of its maximum. Like TDS 500 scopes and some competitors' units, the TDS 700 units offer a mode in which the ADCs always run at the maximum rate, regardless of the sweep speed. In this mode, a number of samples can correspond to a single column on the display. To eliminate aliasing, the scope scans all of these samples and illuminates the pixels that lie between the highest and lowest readings in the column.

The TDS 784A is virtually without a peer. It offers 1-GHz bandwidth on four channels and real-time sampling rates twice as high as the TDS 744A's. Among four-channel, 1-GHz bandwidth, real-time-sampling DSOs that sell for under $35,000, the only competition is Tek's TDS 684A, introduced this year; it costs $29,945 without probes. Unlike the TDS 700 scopes, the TDS 684A doesn't offer InstaVu, a 500k-sample memory option, or random repetitive sampling for periodic waveforms. However, unlike the TDS 784A, which must use random sampling to acquire several 1-GHz-bandwidth signals simultaneously, the TDS 684A acquires four such signals at once in real time at 5G samples/sec.

—by Dan Strassberg

Tektronix Inc, Beaverton, OR, (800) 426-2200. **Circle No. 420**

Analog FPGAs arrive

In an enterprising commercial and technological move, IMP is billing its new electrically programmable analog circuit (EPAC) as the analog counterpart to digital field-programmable gate arrays (FPGAs). Similarities to FPGAs, says the company, are ease of use (for those lacking analog expertise), user programmability, interconnection flexibility, block-level design, and fast programming. The company built analog smarts into the EPAC using "expert cells" that allow rapid development and implementation of analog functions without requiring analog-design expertise, according to IMP.

Such claims may raise the eyebrows of analog experts, who know all too well the many tradeoffs analog design entails. But the company doesn't claim to have a product that can implement all possible analog configurations and performance variations. IMP will carefully target the first and subsequent EPAC devices for particular applications. Each device will combine power, accuracy, and speed features into a set of expert cells for that application. For example, the integrated components of the first available device, the IMP50E10, target signal-conditioning applications in the sensor, instrumentation, and industrial-control markets. The company plans to aim future EPACs at data-acquisition, trimming and calibration, signal-processing, and servo applications.

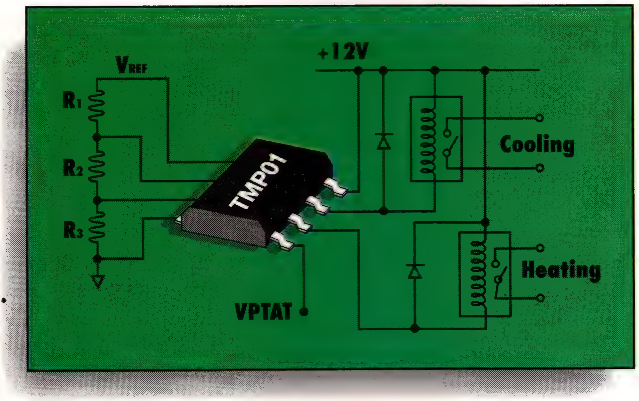
Three years in development, the IMP50E10 electrically programmable analog circuit and Analog Magic software provide designers of analog industrial-control circuits the same flexibility and advantages as digital-FPGA designers enjoy.

The IMP50E10 features up to 18 differential or nine single-ended

(continued on pg 20)

FREE TEMPERATURE SENSOR DESIGN SEMINAR. FOR INFORMATION CALL: 1-708-519-1777

Single-Chip Sensor/Thermostat Simplifies Temperature Monitoring And Control.



Pre-Calibrated.
Accurate.
Affordable.

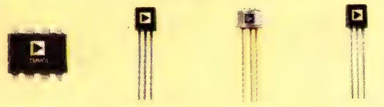
Introducing the TMP01, an integrated single-chip temperature sensor and controller that provides significant advantages over electromechanical devices for general purpose temperature monitoring applications.

The TMP01 is exceptionally easy to use. Upper and lower temperature limits and hysteresis are set by three external resistors, with the exact set point values instantly calculated with accompanying design software. The sensor generates a voltage output proportional to temperature (VPTAT), with a sensitivity of 5mV/K over the temperature range.

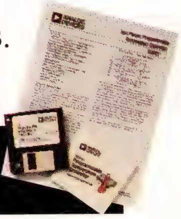
Other TMP01 advantages include low power, single supply operation; 20mA open collector outputs to drive relays or to provide TTL/CMOS logic; over one month of continuous operation from a 9V battery; factory calibration to reduce manufacturing time and costs; and a variety of affordable plastic packaging options, starting at $1.95.*

For free samples, design software and technical information on TMP01, call the number shown below, or simply fax your request to 617-821-4273.

Sensible Temperature Designs Start With Analog Devices



TMP01	**AD22100**	**AD590**	**AD592**
General Purpose, Programmable, Sensor and Controller	Low-Cost V_{out} Temp Sensor	High Accuracy I_{out} Temp Sensor	Low-Cost I_{out} Temp Sensor



FREE SAMPLE, DESIGN SOFTWARE AND LITERATURE Call 1-800-ANALOGD (262-5643)†

ANALOG DEVICES
Analog. Digital. Solutions.

Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106.
Distribution, offices and application support available worldwide.

---

* USD 1,000s, recommended resale, FOB U.S.A.

† Outside U.S., please call 617-461-3392.

CIRCLE NO. 93

inputs, three single-ended outputs, and 22 user-programmable modules, including filters, buffers, comparators, and amplifiers, such as programmable-gain and S/H types. General performance parameters include a 0- to 80-dB gain range, a 125-kHz signal bandwidth, which you can limit to 15 kHz using internal filters, 12-bit overall linearity for a 3V signal range, and a 70-μA to 16-mA supply current on a 5V supply. The hardware architecture comprises input, core, and output sections, each containing some of the 22 user-programmable cells. For example, the input stage includes programmable multiplexers, filters, a summing stage for offset shifting, and a programmable-gain instrumentation amplifier. The core section comprises linear amplifiers with flexible interconnect that allows the device to achieve its high gain. You can configure various output blocks to compare, sample and hold, and implement a buffered reference.

EPACs also include a utility block that's not part of the direct signal path. Modules in this block include a programmable clock generator, power-down control, which you can use to shut down the IC globally or selectively, an auxiliary op amp with pins for connecting external feedback circuitry, and a probe module for viewing the outputs of various internal blocks.

The company spent three years developing both this hardware architecture and the corresponding block-level-design software tool, Analog Magic. Using the software, designers can configure and program the functionality, interconnect, and performance of EPAC devices. The software, an object-oriented C++ tool, runs on Windows-based PCs, displays all the available resources on a given EPAC, and guides users through the programming of each module. The software also includes a design checker to verify style and design practice relative to EPAC devices as well as a soft-probe feature to aid real-time design debug and test. The software does not perform simulation in the same sense as an FPGA. Instead, the company guarantees a what-you-see-is-what-you-get result, including no loading effects and unconditional output stability. In future versions of the design system, the software will be able to generate a netlist that you can use for larger system simulations in Spice, Saber (Analogy Inc), and LSIM (Mentor Graphics Corp).

IMP builds EPACs using its mixed-signal 1.2-μm electrically erasable CMOS process with EEPROM. EEPROM stores the circuit configuration in nonvolatile memory, and static memory permits real-time EPAC programming, which allows users to make quick in-system design changes without affecting the default or power-on configuration in EEPROM. The company quotes typical programming times of 200 μsec to 275 msec.

The IMP50E10 costs $25 (100), but, as with digital FPGAs, the company provides a migration path to cheaper mask-programmable analog circuits (MPACs). According to IMP, EPAC conversion risks are much lower than with FPGAs because the cost reduction doesn't come from routing reduction but from the removal of EEPROM overhead. Thus, the company says no performance differences will exist between an EPAC and its corresponding MPAC.

The company will sell EPACs through distribution as well as to OEMs. A $1249 EPAC full development system comprises the Analog Magic software, a programming board in a sturdy enclosure, an interconnect cable, a daughterboard with a pretested IMP50E10 chip, and two general-purpose application boards. A more basic, $299 development system contains just the software and a small, simple programming board. Samples will be available by Nov 1, and production quantities will be available in January.

—by Anne Watson Swager

IMP Inc, San Jose, CA, (408) 432-9100. **Circle No. 421**

Superscalar RISC μPs scale performance heights

The designers at Digital Semiconductor, IBM/Motorola, Silicon Graphics, and Sun Microsystems have been busy lately exploiting leading-edge computer architectures to develop high-performance μPs for workstations. These CPUs can issue four instructions/cycle and have SPECint92 and SPECfp92 numbers that exceed 200 and 300, respectively, taking superscalar to a new level. Digital estimates that its new processor will hit 330 SPECint92 and 500 SPECfp92 when running at 300 MHz.

Digital's 21164 has 9.3-million transistors and—for the first time on a μP—a level-two cache. This unified, three-way set-associative, 96-kbyte cache provides backup for the chip's level-one, 8-kbyte instructions and data caches. Digital's previous-generation Alpha, the 21064, had 16-kbyte, level-one caches. The 21164's designers reduced the cache size to meet a 6.6-nsec access time (two clock cycles at 300 MHz) because larger memory arrays take longer for address and data propagation. Access to the level-two cache requires eight cycles, and an external level-three cache would chew up 12 clock cycles.

To help increase loading efficiency, the 21164 contains merge logic that looks ahead to see if more than one reference is being made to the same cache block. The merge logic potentially compresses up to 20 loads in a row but only if a 21164 compiler generated the code.

Digital's CPU has a seven-stage integer pipeline that contains two integer units. It also includes a nine-stage floating-point unit that can simultaneously issue an addition operation and a multiplication operation in one cycle. The 21164 also features considerably reduced execution time for many instructions compared with the 21064. For example, the 21064 took 19 to 23 cycles to perform an integer multiply; the 21164 takes eight to 16 cycles.

(continued on pg 22)

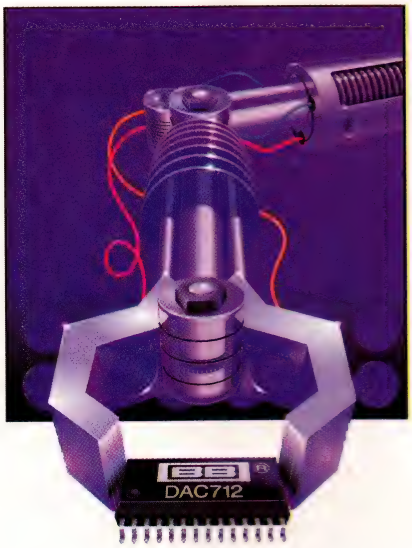
NEW

D/As for Every Application

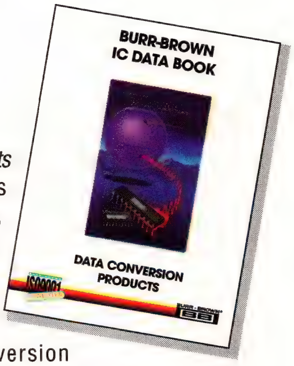
16-Bit D/A Ideal for Industrial Applications

DAC712 is a 16-bit D/A designed and specified for industrial applications—it's ideal for ATE equipment, analog I/O boards, robotics, process controllers, and similar designs. A full-function device, it's complete with a precision ±10V temperature-compensated voltage reference, ±10V output amplifier, and 16-bit port bus interface. Featuring a fast, 16-bit parallel, double-buffered interface for direct connection to industrial buses, DAC712 beats the competition in price, power, and size. It is packaged in a 28-pin, "skinny" 0.3in DIP—half the size of our competition! Power dissipation is a low 600mW, and prices have been cut, too! It's also available in a 28-lead SOIC package and priced from **$13.00** in 100s.

Circle No. **111**



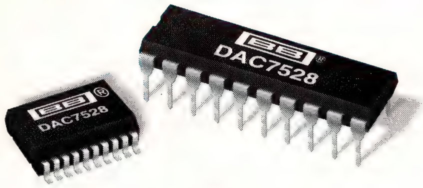
New Data Conversion Products IC Data Book



The *Data Conversion Products* IC Data Book contains detailed product descriptions, complete specifications, applications tips, and ordering information for our broad line of high performance, data conversion products. Over 950 pages, it offers more than 25 new data conversion solutions. New products profiled include: A/D and D/A converters, data acquisition components, sample/hold amplifiers, V/F converters, and multiplexers. The *Data Conversion Products* Data Book is **FREE** from any Burr-Brown sales office or representative. Or, call the Literature Hot Line at **(800) 548-6132** to get your copy.

Circle No. **112**

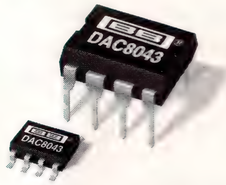
Multiplying



Dual, CMOS, 8-Bit D/A Delivers Competitive Performance and Price

DAC7528 is a dual, 8-bit, CMOS multiplying D/A converter—it's a pin for pin replacement for the industry standard "DAC7528". Use it for digitally controlled filters, disk drives, motor control systems, X-Y graphics, programmable gain/attenuation, and auto calibration applications. Key specs are: double buffered data latches, single 5V supply operation, ±1/2LSB linearity, four-quadrant multiplication and TTL compatibility. DAC7528 is available in a 20-pin DIP, SOIC, and die. Priced from **$4.14** in 100s, delivery is immediate and off-the-shelf.

Circle No. **113**



12-Bit Serial Input D/A in 8-Pin Mini-DIP & SOIC

DAC8043 is a 12-bit, CMOS multiplying D/A converter that's a pin for pin replacement for the industry standard "DAC8043". Its small size, low cost, and high performance make it perfect for auto calibration, motion control, programmable amplifiers/attenuators, and digitally controlled filters. Key specs are: 12-bit accuracy, 3-wire serial interface, ±1/2 LSB INL/DNL, ±1LSB gain accuracy, 5ppm/°C gain tempco, and TTL/CMOS compatibility. Operating from a +5V supply, DAC8043 is available in an 8-pin Mini-DIP, SOIC, and die. Priced from **$7.47** in 100s, delivery is immediate and off-the-shelf.

Circle No. **114**

Low Cost, High Accuracy 16-Bit D/A

DAC56 is a complete 16-bit, monolithic D/A—at **$5.83** in 1000s, it's the most cost-effective, highest accuracy D/A available for the industrial market today! It's self-contained with a stable, low noise, internal zener voltage reference; high speed current switches; a resistor ladder network; and a low noise output op amp—all on a single chip. Key specs are: 0.012% linearity errror (max), 12-bit guaranteed monotonicity, 1.5μs voltage out settling time, 350ns current out settling time, ±3V voltage out, and ±1mA current output. Use it for process control, ATE equipment, and multiple channel applications. Specified over the 0°/70°C temperature range, DAC56 is available in 16-pin DIP and SOIC packages.

Circle No. **115**

BURR-BROWN
ISO9001
CERTIFIED

BURR-BROWN®
BB

Burr-Brown Corporation • P.O. Box 11400 • Tucson, AZ • 85734-1400 • Call **(800) 548-6132** or FAX **(602) 741-3895.**

How much does all this performance cost? Although the 300-MHz version sells for a mere $2669 (5000), the 21164 also exacts a power premium: Even though it runs on a 3.3V supply, it still consumes 50W and requires plenty of cooling.

Silicon Graphics' T5 hasn't reached the product stage yet, so it still retains is code name. Toshiba and NEC have licensed the architecture and will begin turning out products by the first quarter of next year; they have not yet set prices. The T5 operates at 3.3V, consumes 30W, and has 6.4 million transistors.

Although the architecture of the T5 is new, its designers decide that it would run unrecompiled R4000 code without a performance degradation. Even at a slower 200 MHz, the T5 will still give Digital's 21164 a good race: Estimated performance is 250 SPECint92 and 350 SPECfp92—blowing the doors of the previous-generation R4000.

The T5 can dispatch instructions simultaneously to five pipelines—floating-point add, floating-point multiply, two integers, and a load/store—after instructions go through a two-stage instruction fetch-and-decode unit. The execution units can complete instructions and write their results out of order. To support this out-of-order execution, the T5 maintains an instruction-status table to determine the instructions waiting to graduate and to put the instructions in order. When handling out-of-order execution, a completed instruction may never graduate because an exception or branch could invalidate the results. For this reason, an instruction may complete, but, until graduation, its results are tentative and may be discarded.

Unlike the 21164, the T5 has large (32-kbyte) primary-instruction and data caches. The processor supports 512 kbytes to 16 Mbytes of external secondary cache and uses a 128-bit data path to move data. The level-two cache must comprise synchronous SRAMs to achieve a high enough bandwidth to feed the processor.

The T5 also facilitates designing tightly coupled multiprocessing systems. To accomplish this goal, the CPU has a 64-bit cluster-bus configuration that allows the direct connection of four T5 processors. Attaching the T5s to an external agent, or cluster coordinator, creates a cluster bus that manages the flow of data within the cluster.

Sun's UltraSPARC implements the SPARC-V9 specification, a version of the scalable processor architecture (SPARC). SPARC-V9 maintains upward binary compatibility with the 32-bit SPARC-V8 and extends the architecture with support for 64-bit virtual addresses and integer data sizes up to 64 bits (including 64-bit registers), 32 double-precision floating-point registers (up from 16), 64-bit integer multiply and divide instructions, and conditional-move instructions. V9 also defines a hardware mechanism that uses compiler technologies that streamline the prefetching of data and instructions. Other extensions facilitate the design of superscalar processors and a tighter relationship between operating systems; this includes support of lightweight threads, faster context switching, and object-oriented software.

UltraSPARC is the first silicon rendition of the V9 specification. Sun designed the CPU with a nine-stage pipeline in which the first two stages comprise the instruction fetch and decode. Sun also includes a 2-bit dynamic branch-prediction mechanism, a key ingredient of the prefetch unit. As the 16-kbyte instruction cache fills, the CPU uses 2 extra bits/instruction to tag on information related to the branch prediction for that instruction.

The CPU's pipeline also encompasses two integer ALUs, five floating-point/graphic units, and a load/store unit. Special instructions for the graphic units (which V9 does not designate) allow UltraSPARC to support graphics and multimedia data manipulation, including hardware support for 2 and 3D imaging, video processing, and image compression. UltraSPARC uses data buffers to isolate the level-two cache from the system bus. These buffers enable overlapping of system transactions and perform error detection/correction. The processor contains an on-chip level-two cache controller, and the system bus can run at one-half or one-third of the processor frequency. Sun states that instructions and data can pass between the level-two cache and the CPU at 2.6 Gbytes/sec.

UltraSPARC is estimated to run at 200 to 300 SPECint92 and 250 to 350 SPECfp92 at 167 MHz. The company is planning production for the third quarter of next year, and prices are unavailable. Texas Instruments will manufacture the system using a 0.5-μm process.

IBM/Motorola's PowerPC 620 takes the PowerPC architecture to the 64-bit level and rounds out the PowerPC's portfolio: The 601 targets desktop PCs, the 603 handles low-power applications, the 604 fits in mainstream workstations, and the 620 fulfills the needs of high-end servers. The 620 offers six execution units encompassing a five-stage pipeline. The execution units comprise a branch, three integers, a floating-point unit, and a load/store. Each unit contains two to four reservation units for holding instructions so that the CPU can reduce data dependencies and pipeline bubbles. Similar to the T5, the 620 performs out-of-order execution and in-order graduation.

Unlike other PowerPC CPUs, the 620 can perform both static and dynamic and branch prediction. Another difference is the CPU's huge caches. The 601 has a 32-kbyte unified cache, and the 620 implements a Harvard architecture with 32-kbyte instruction and data caches. Both caches are eight-way set-associative, and the data cache handles write-through and write-back modes.

Another key feature of the 620 is the 128-bit level-two cache interface. The unified level-two cache can be clocked at one, one-half, or one-third the frequency of the processor clock. The CPU also has a 40-bit address bus. The 620, with its 6 million transistors is expected to pull in benchmarks of 225 SPECint92 and 300 SPECfp92 at 133 MHz. Volume production and pricing are still a year away.—by Markus Levy

Digital Semiconductor, Hudson, MA, (508) 568-6868. **Circle No. 422**

IBM Microelectronics Inc, Fishkill, NY, (800) 426-0181. **Circle No. 423**

Motorola Inc, Austin, TX, (512) 891-2000. **Circle No. 424**

Silicon Graphics, Mountain View, CA, (415) 390-2136. **Circle No. 425**

Sun Microsystems, Mountain View, CA, (415) 779-8119. **Circle No. 426**

SIEMENS

Isn't It Time To Expect More Innovation From Your Optocoupler Supplier?

The SO-8 is the latest example of why Siemens innovation is a cut above.

At Siemens, innovation means more than just turning out this year's version of last year's product. Or adding "bells and whistles" to make a half-baked product seem more exciting than it actually is.

Like you, we take innovation seriously. Our unique products have earned us a reputation worldwide for functionality, flexibility and reliability, and have helped us become the fastest-growing optocoupler supplier in the world.

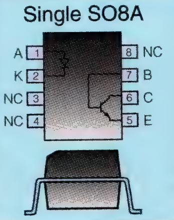
The latest example of this dedication to innovation is the SO-8 family of optocouplers, the world's first with 2 channels (dual) in a surface mount package. In fact, it's the highest-density optocoupler in the world. That's innovation the competition can't touch.

And our wide range of products are backed by the world-class service and technical support you'd expect from an industry leader.

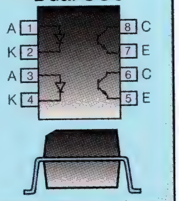
Call us today for a complete SO-8 data kit. And discover innovation that's a cut above the competition.

Part #	CTR	Part #	CTR
IL206A	63-125%	ILD206	63-125%
IL207A	100-200%	ILD207	100-200%
IL213A	100% Min.	ILD213	100% Min.

Single SO8A



Dual SO8



CTR= Current Transfer Ratio

1-800-77-SIEMENS

Call Today, And Ask For Extension 3.

© 1994 Siemens Optoelectronics, Inc.

CIRCLE NO. 106

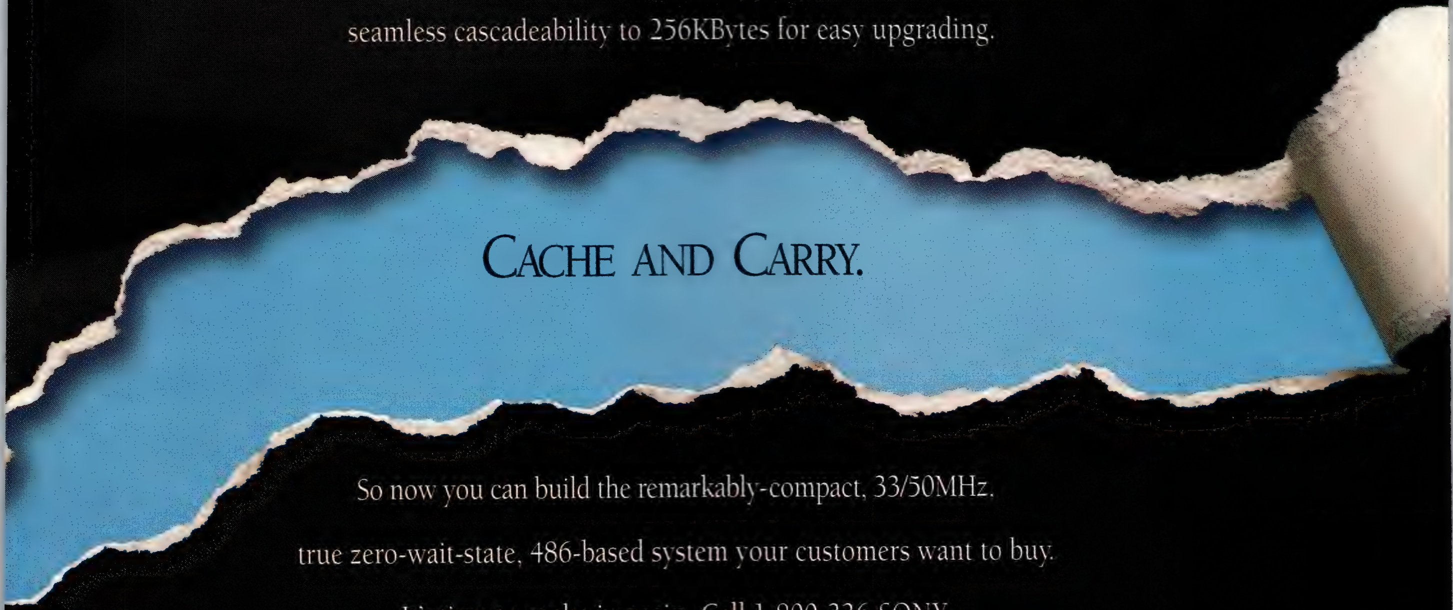
SONY
SONY
SONY
CXK784861Q
SONY
CXK784861AQ
SONY
CXK78V4861AQ
SONY
CXK78V4861BQ

SONY

Sony Cache, our unique, integrated cache memory subsystem-on-a-chip, has spawned a family. Four new 128KByte, monolithic 28mm chips complete with high-speed data RAM, tag RAM and control logic already built in for all 486-based systems.

Now for the first time, you have the low-power enabling technology to bring level-two cache performance to your mobile 486 laptops, notebooks and PDA's.

All four chips come in an easy-to-adapt look-aside configuration. Plus they support write-back as well as write-through protocol. And provide seamless cascadeability to 256KBytes for easy upgrading.


CACHE AND CARRY.

So now you can build the remarkably-compact, 33/50MHz, true zero-wait-state, 486-based system your customers want to buy. It's time to cache in again. Call 1-800-336-SONY.

We make the chips. You make the history.

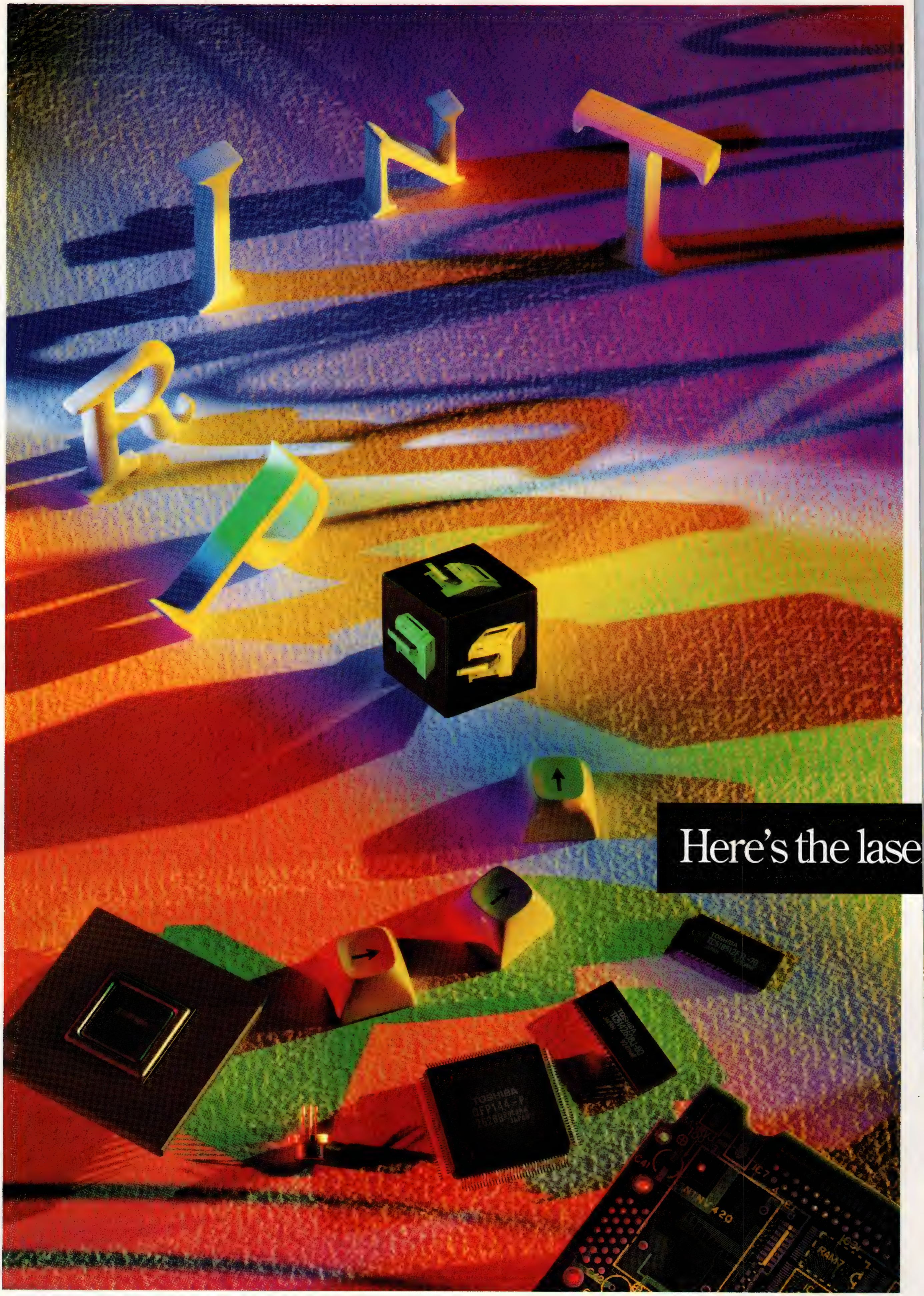
The Growing Sony Cache Family

FEATURE	CXK784862Q*	CXK784861Q	CXK784861AQ	CXK78V4861AQ	CXK78V4861BQ
VCC	5V	5V	5V	3.3V	3.3V/5V I/O
Cache Size	256KB	128KB	128KB	128KB	128KB
Freq. (MHz)	33/50	33	50	33	33/40
Cache Protocol	WT	WT/WB	WT/WB	WT/WB	WT/WB
Power Mgt.	No	No	No	No	Yes
Cascadeability	Up to 1MB	Up to 256KB	Up to 256KB	Up to 256KB	Up to 256KB

*This first Sony Cache package was announced in March. All five chips are designed exclusively for 486 processors. All come in a 28mm square, 160-pin PQFP package, have a zero-wait-state 2-1-1-1 cache burst cycle, a look-aside configuration, and two-way set associative mapping. Data-RAM is configured 32K x 36 x 2 for the CXK 784862Q and 16K x 36 x 2 for all others; tag - RAM is 4K x 20 x 2.

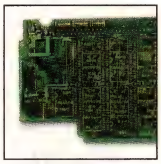
© 1994 Sony Electronics Inc. MASIC and Sony are Trademarks of Sony.

CIRCLE NO. 85

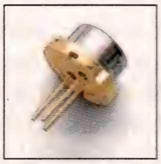

PRINT
Here's the lase
TOSHIBA
QFP144-P
JAPAN
RAM7

What's the story on Toshiba? System solutions.

It's true. Nobody can add more value to your system more ways than Toshiba. From 32-bit RISC processors and design-defining ASICs to optimally-featured microcontrollers, right down to multi-layer PCBs, we're definitely thinking "big picture" when we look at your system plans.

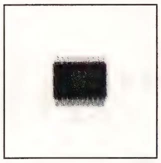

Printed Circuit Board

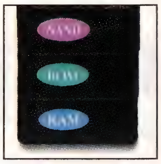
Pseudo SRAM


Visible Laser Diode

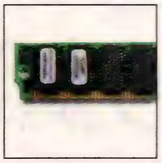
Mask ROM

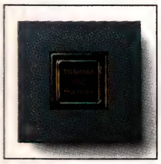
ASIC


Logic



Memory Cards


DRAM Module


RISC Microprocessor

DRAM

Let us prove the point using an up-to-date laser printer as just one example. You'll put our wide selection of DRAM densities and organizations to good use as main memory and soup-up performance using our SRAMs as buffer memory. We've got the MROM you need for code storage. And memory cards for fonts, buffers and custom options.

ersion of Toshiba's system-smart story.

We can provide the printed circuit board, too, along with a RISC-based CPU and microcontrollers for the print engine motor, glued together with our CMOS logic. Our finely-architected 250ps ASICs with up to 500,000 usable gates, provide a higher level of functional integration for essential market differentiation. Then our visible laser diodes and photo interrupters can make light of it all.

In an era of ever closer partnerships, our broad, broad line of semiconductors and ICs and our finely-honed system sensibilities give us a competitive advantage. More importantly, they give *you* a competitive advantage. By helping you keep a lid on costs and get to market sooner. And when success arrives, Toshiba's legendary manufacturing prowess assures you uninterrupted supply.

Of course, your system's quality is only as good as the sum of its parts. So we take great measures to assure the highest quality components on the market today. We're proud of our ISO 9000 certification in Japan and expect certification in the U.S. by year end. And we top it all off with an unrivaled customer story.

End of story? No, that's just the beginning. Call us today for all the ways we can make your next design a little more elegant, a little more effective and a lot more competitive. 1-800-879-4963.

In Touch with Tomorrow
TOSHIBA
TOSHIBA AMERICA ELECTRONIC COMPONENTS, INC.

Please call me, Circle No. 98   Send more information, Circle No. 99

©1993 Toshiba America Electronic Components, Inc.

HDQ-92-073

NCR

FAST Track to FAST SCS

90's Challenges. The 90's demand higher levels of performance and faster delivery than ever. Time-to-market, technological demands, and changing user needs make fast, simple SCSI seem as elusive as the horizon. To stay ahead in these challenging times, you need products you can count on, with proven ability to deliver the quality and reliability your customers require.

90's Products. After over a decade of industry leadership, NCR is still working hard to meet your needs and the challenges of the 90's. The NCR 53C90 family of SCSI Controllers is constantly evolving, implementing and offering state-of-the-art products. For example, the NCR 53C90 family supports multiple bus architectures, advanced SCSI-2 commands, fast SCSI data transfers and provides our exclusive TolerANT® SCSI driver and receiver technology, for reliable data transfers in every SCSI system.

90's Solutions. The SCSI challenges o
90's can't be solved with silicon alone.
quality and service provide you with the
competitive edge that can make your
industry leading designs a reality. Wheth
you require SCSI-1 or fast SCSI-2, in an
system architecture, NCR has the produ
meet your needs today. You can count o
to keep you on the fast track with the ri
technology, at the right price, at the righ
time for all your SCSI requirements.

The NCR 53C90 Family

Proven Performance for the 90's and Beyond

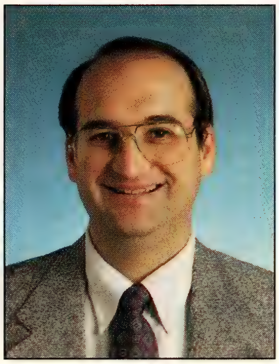
CIRCLE NO. 65

NCR SCSI: Real Products, Real Solutions, Real Fast!

SCSI	FAST SCSI*	*NCR Fast SCSI devices transfer SCSI data at 10 MB/s synchronous or 7 MB/s asynchronous
53C90A	53CF90A	Single-bus architecture; SCSI sequences controlled by hardware state machine to minimize host intervention
53C90B	53CF90B	Adds pass-through parity for increased system reliability
53C94	53CF94	Adds split-bus architecture for more flexibility
53C96	53CF96	Adds support for differential transfers

*For more information abou
NCR SCSI products
and a free poster,
call 1-800-334-5454.*

INCREASING SCSI RELIABILITY
TolerANT
ACTIVE NEGATION TECHNOLOGY



The music processor

As I write this, I am sitting in Davies Symphony Hall waiting to hear the San Francisco Symphony play the first notes of Mahler's Eighth Symphony. Mahler's Eighth is a huge piece, requiring 125 musical instruments and a chorus of hundreds. (My brother Jim sings in the chorus.) That Mahler could orchestrate such a complex composition boggles the mind.

We in the electronics industry owe a debt to music. It's a debt that we seldom recognize or acknowledge. Part of our technical ability to coordinate millions of transistors and millions of lines of code stems from our rich orchestral heritage. Perhaps this link between music and system design explains why so many great electronic designers listen incessantly to music while they create.

"We in the electronics industry owe a debt to music—one we seldom recognize or acknowledge."

Mahler's mind was able to coordinate many parallel processes—voices and instruments—to produce an overall musical effect. I find his symphonic work strikingly similar to the orchestrated operation of a very complex electronic system. At the simplest level, you might consider each instrument or voice as a note generator. Even at that level of complexity, orchestration at the magnitude of Mahler's Eighth is amazing.

However, an orchestra doesn't consist of simple note generators. The conductor—in this case, Herbert Blomstedt—independently controls each instrument and each voice. The conductor interprets a composition so that it's never performed the same way twice. The orchestra is a music processor comprising hundreds of independent processes (musicians) all coordinated by one master controller, the conductor. Viewed this way, an orchestral performance is far more complex than most of today's electronic applications. Until we can produce works as complex as Mahler's Eighth, we can continue to learn new aspects of system design from the centuries-old heritage of orchestral music.

Steven H. Leibson

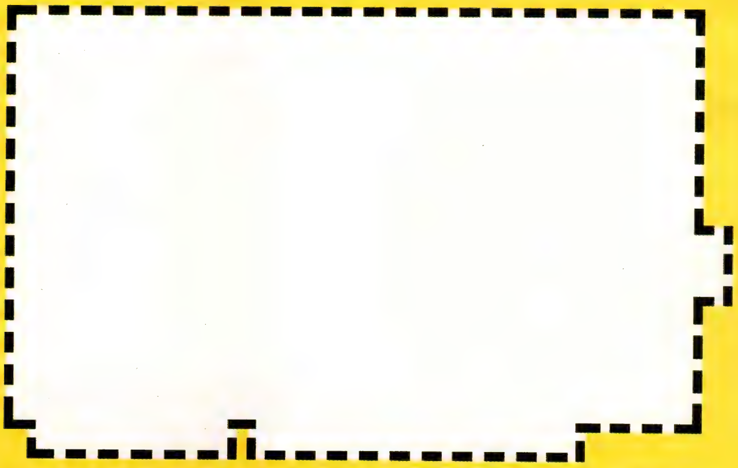
EDITOR IN CHIEF

Jesse H Neal
Editorial Achievement Award
1990 Certificate, Best Editorial
1990 Certificate, Best Series
1987, 1981 (2), 1978 (2), 1977, 1976, 1975

American Society of
Business Press Editors Award
1994, 1991, 1990, 1988, 1983, 1981

Send me your comments via fax at (617) 558-4470, or on the EDN Bulletin Board System at (617) 558-4241, 300/1200/2400 8,N,1. From the Main System Menu, enter ss/soapbox and select W to write us a letter.

How AMD He
Make A Fortune



Typical Ethernet adapter card: 4 x 6 inches.

Typical SCSI adapter card: 4 x 7 inches.

Everyone could use some extra space. And that's exactly what Compaq® offers end-users in their new Deskpro® XL. All with the help of AMD,® of course.

AMD's new PCnet™-SCSI controller enabled Compaq's designers to create a high-performance, plug-and-play PC with 32-bit Ethernet and SCSI on the motherboard—eliminating the need for separate Ethernet and SCSI adapter cards.

Your next PC design can have an equally lucrative future, since PCnet-SCSI supports the standards end-users demand: Ethernet for network access. SCSI for peripherals in applications like multimedia. And PCI, the leading high-speed bus architecture. It even comes with a complete selection of Network Operating System and peripheral drivers.

AMD's PCnet-SCSI chip puts Ethernet and SCSI capabilities right on the motherboard of the new Compaq Deskpro XL.

PCnet-SCSI covers only 7.5 square inches of motherboard real estate and takes only one PCI load. Which leaves plenty of PCI loads

One AMD Place, P.O. Box 3453, Sunnyvale, CA 94088. ©1994 Advanced Micro Devices, Inc. PCnet is a trademark. AMD and the AMD logo are registered trademarks of Advanced Micro Devices, Inc. Compaq and Deskpro are registered trademarks of Compaq Computer Corporation. Other product or brand names mentioned are property of their respective holders.

ped Compaq
In Real Estate.

AMD's PCnet-SCSI controller: 1 1/8 x 1 1/8 inches.

and open slots for future upgrades. So there's always room for expansion.

What's more, PCnet-SCSI is software and pin-compatible with other members of the PCnet family. So you can configure your systems to offer either Ethernet, SCSI, or both. All in one design.

Best of all, you can add all this functionality for less than $50—compared with a major investment in adapter cards, installation, and support.

For more information on PCnet-SCSI and the entire PCnet family, call AMD today. Because with the right connections, you can make a fortune, too.

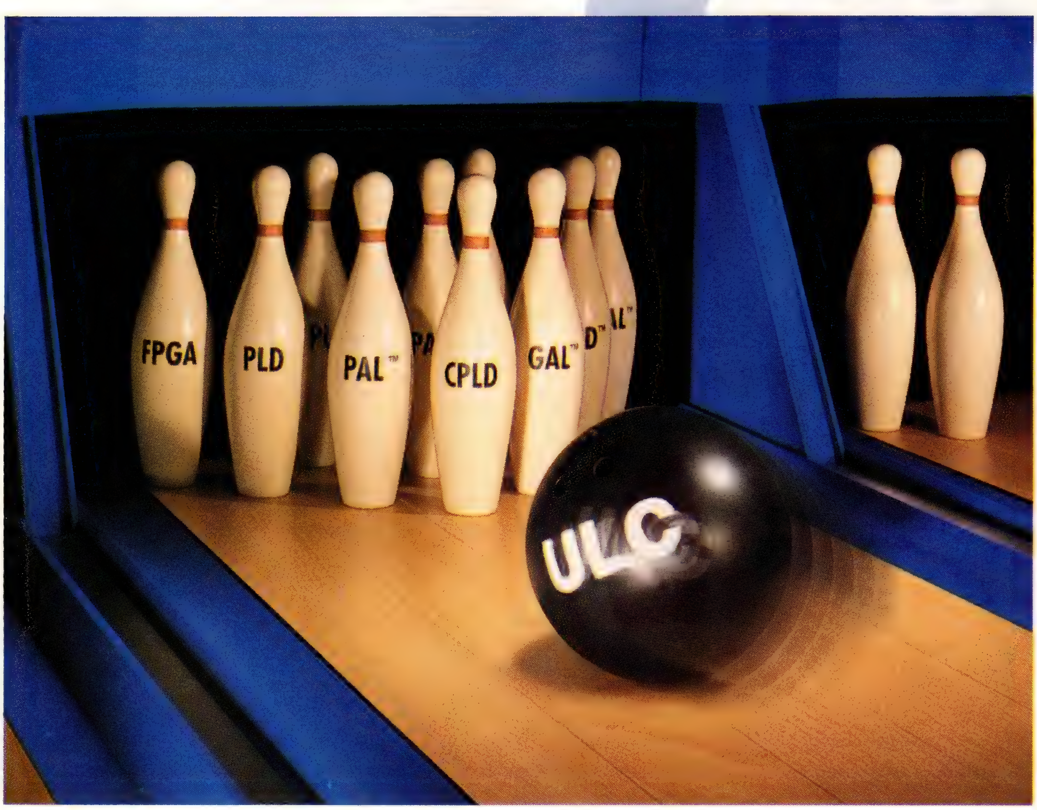
800-222-9323

Ask for Literature Pack 19R.

Advanced Micro Devices

ULCs™ from MATRA MHS :

The low-cost, risk-free breakthrough in PLD and FPGA conversion.



ULC™ is a trademark of MATRA MHS. Xilinx®, Actel®, Altera®, Lattice®, Atmel®, MACH® are registered trademarks in their respective companies.

If you're tired of paying high prices for FPGAs and PLDs, it's the right time to switch to ULCs™ from MATRA MHS, (ISO 9001 certified).

Our Universal Logic Circuits offer a guaranteed, risk-free alternative to any Programmable Logic Device. What's more, they can lower your component costs by a stunning 25 to 75%.

ULCs™ provide the following benefits :

- no NRE,
- no risk (simply cancel your order if the prototype doesn't work),
- no sign-off requirements thanks to patented "Verify Before Silicon" technology,
- total pin-to-pin compatibility with any PLD,
- low power 3.3V version available.

Because we undertake all conversions based on your existing inputs, including FPGA/PLD files, Master Unit and Simulation files (when available), no other solution is easier and more hassle-free for you.

There's a ULC™ conversion solution available for Xilinx®, Actel®, Altera®, Lattice®, Atmel®, MACH®, 22V10 and many more.
Every solution features unsurpassed dependability.
In fact, our ULC™ family enjoys a proven track record of over 500 successful conversions.
To find out how you can break through to lower component costs, call us today at :
1-800-554-5565, ext. 916

TEMIC

Members of the TEMIC Semiconductor Division : Telefunken Semiconductors, Siliconix, Matra MHS, Dialog Semiconductor

TEMIC Sales Offices
FRANCE : Tel. (33) 1-30 60 71 08 - GERMANY : Tel. (49) 7131 67-0 - ITALY : Tel. (39) 2-332 121
SCANDINAVIA : Tel. (46) 8-733-0090 - UNITED KINGDOM : Tel. (44) 344-485757
HONG KONG : Tel. (852) 378-9789 - JAPAN : Tel. (81) 3-5562-3321
USA : 2201 Laurelwood Road, Santa Clara, CA 95056 - Tel. (408) 748-93 62 - Fax : (408) 748-04 39

CIRCLE NO. 139

SAATCHI & SAATCHI BUSINESS COMMUNICATIONS GROUP

Reverse-engineering and conservation

I enjoyed your editorial "Reverse-engineering of the third kind" (*EDN*, July 21, 1994, pg 31) and agree with you. However, you left out reverse-engineering of the fourth kind, which is probably the most common type of all, certainly in my experience of late.

This involves the need to reverse- or re-engineer a product so that it will perform as expected or to enable its service life after the original manufacturer has arbitrarily decided that it's no longer useful.

In the first instance, reverse-engineering is a simple necessity, in many instances to make the product work as advertised, because the current design philosophy in the industry doesn't provide nearly adequate product testing and bug correction before release. I suppose the theory is that it's too expensive a process or that only 10% of the users will complain—and, besides, we have no intention of real product support anyway. Hence, the old axiom that it costs 20 times as much to fix a problem in a released product than to design it right to begin with doesn't apply.

In the second instance (a natural progression of the first), it is next to impossible to obtain documentation from manufacturers once they have decided, in their infinite wisdom, that the useful life of the product has expired. It escapes me what "company confidential secrets" you could ever obtain from documentation for a piece of equipment that is a few years old and is no longer in production or supported by the manufacturer—even though it may still be exactly what's needed for your specific application, and it's desirable to keep it working for a while longer. We don't always need the newest or the nicest to get the job done.

Although some would consider this fourth kind a theft of intellectual property, I consider it to be simply a way of conservation and reducing the waste stream. Otherwise, we'll bury ourselves with waste equipment, but that's a subject for another time.

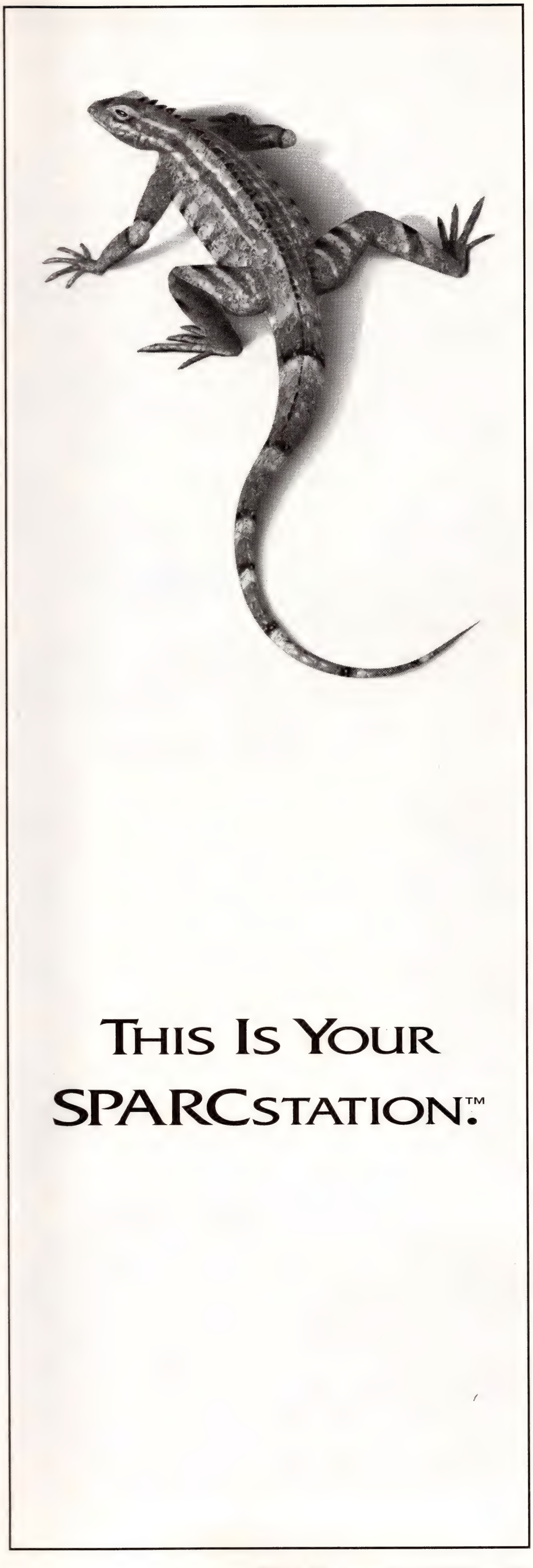
Don Pomeroy
Milestone Laboratories
Manchester, NH

Skepticism grows over fuzzy-logic future

Reading "Weigh the benefits of fuzzy-logic vs classical control in a disk-drive spindle" (*EDN*, July 7, 1994, pg 137) reinforces my skepticism regarding this subject. I have yet to see a fuzzy-logic application that improves on a well-designed classical system.

In the example given, the fuzzy controller reaches its stable target speed about 10 to 15% sooner than the simple proportional plus integral (PI) system.

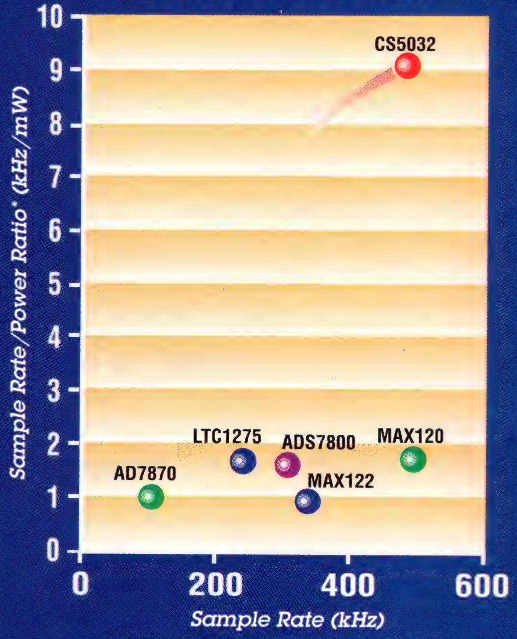
If this performance is really required, I would change the classical system to add a start-up mode, in which full power would be applied to the motor. A comparator driven from the tachometer would switch to PI control when the target speed is reached (the comparator could be set slightly below target speed to allow for control-system lag and stored electrical energy in the motor). I would also preset the integral term in the PI system to the approximate final value determined by experiment.



The next 12-bit ADC standard drives speed/power performance to new heights.

CRYSTAL
CS5032
IT'S ACCURATE.
IT'S CRYSTAL.

THE CS5032 DELIVERS
500kHz FOR ONLY 55mW



*Datasheet specifications for -55°C/125°C

CRYSTAL
SEMICONDUCTOR CORPORATION
1-800-550-5030

CIRCLE NO. 27

This system would give no initial overshoot and a small initial correction to the final speed.

Most important, it's a lot simpler than a microprocessor with 717 bytes of instruction code.

Robert J Rorden, Senior EE
Coherent Inc
Palo Alto, CA

Reader reports AND-gate inaccuracy

I just read "New philosophy aids shift from schematic-based to HDL-based design" (EDN, Aug 4, 1994, pg 119) by Charles F Shelor. On pg 119, Shelor cites a reference: "Looking at Fig 1, digital circuit designers will immediately recognize U1 as an AND gate, U2 and U4 as rising-edge-triggered D flip-flops, and U3 as an exclusive-OR gate."

The problem is that the gate referred to as U1 in the figure is not an AND gate but an OR gate. I understand that this circuit is for illustrative purposes only, but it should at least correlate with its text callout.

Bob Trautman, Research Specialist
Lockheed Missiles & Space Co

Be wary of VHDL bandwagon

Although I enjoyed reading "VHDL emerges as a commercial design tool" by Karen Bartleson (*EDN*, August 18, 1994, pg 84) and share her enthusiasm for hardware-description languages, I strongly advise design and CAD engineers to consider Verilog HDL before blindly rushing to adopt VHDL. Verilog's syntactical kinship to C permits designers to learn it quickly and to write terse, readable, accurate code efficiently and cost-effectively. The Verilog equivalent of Bartleson's 16-bit VHDL counter model would be half as long and far more reader-friendly.

Before investing money and time to learn VHDL, the C-literate design engineer should try a free taste of Verilog by downloading the student version of the VeriWell/'386 simulator from Wellspring Solutions (Sutton, MA).

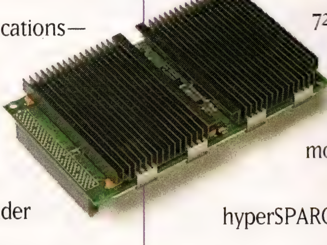
John A Eldon
Principal Systems Engineer
Raytheon Semiconductor
San Diego, CA

Sound off

"Signals & Noise" lets you express your opinions on issues raised in the magazine's articles or on any engineering-related topic. Send letters to *EDN*, 275 Washington St, Newton, MA 02158; fax (617) 558-4470. Or use *EDN*'s bulletin-board system at (617) 558-4241: From the Main System Menu, enter ss/soapbox, then W to write us a letter. You'll need a 2400-bps (or less) modem and a communications program set for 8,N,1. *EDN* reserves the right to edit letters for clarity and length.

This Is Your SPARCstation™ On hyperSPARC.™

MONSTER 90 MHz QUAD-PROCESSOR PERFORMANCE ROARS ONTO THE DESKTOP. Designed to fit twice as many processors in the same space as original-equipment upgrades, ROSS' single-, dual- and quad-processor hyperSPARC upgrades deliver maximum performance—especially from today's sophisticated multi-threaded applications—without sacrificing an SBus slot. Finally, Sun® system users can realize the performance gains of multiprocessing (MP), running under both Solaris® 2.x's multi-threaded environment *and* SunOS 4.1.3.



ROSS upgrades deliver state-of-the-art performance from your existing investment in hardware and software, at a fraction of the cost of your original investment. Guaranteed compatible with existing software, including Solaris, and fully SPARC™ SCD compliant, hyperSPARC modules are also available in 66 and 72 MHz versions. Each module carries a full one-year warranty, and a 30-day money back guarantee.

hyperSPARC modules provide the optimum upgrade path for SPARCstation 10, 20, and SPARCserver™ 600MP-series machines, from the original source of Sun's multiprocessors—ROSS Technology. Whether running multiple processes or one of the new multi-threaded applications, MP machines are today's hottest technology. Discover the monster lurking in your SPARCstation. Call our 800 number, and "just say yes"—or request detailed information and specifications on hyperSPARC multiprocessing.

SunSoft™ SUPPORTED

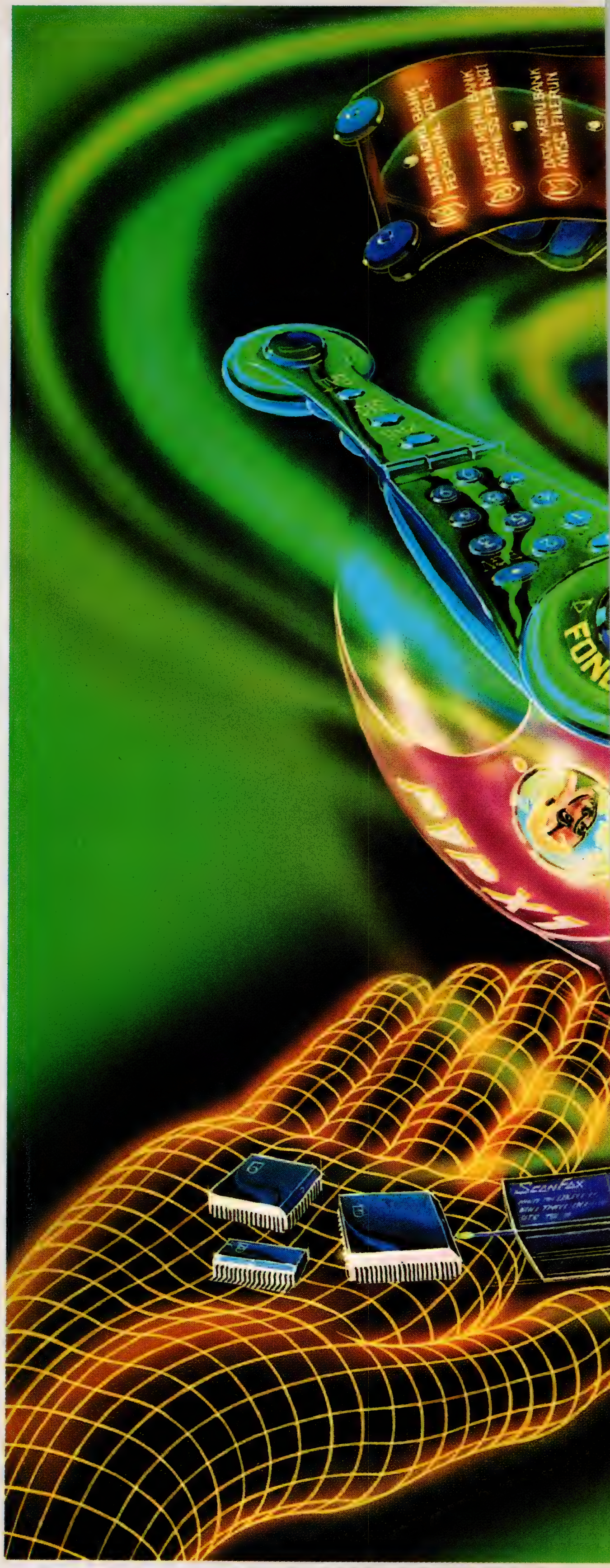
1 • 800 • 774 • ROSS

ROSS®
TECHNOLOGY, INC.
A Subsidiary of Fujitsu, Ltd.

5316 Hwy 290 W., Austin, Texas 78735 • (512) 919-5207 FAX (512) 919-5200 • E mail: ROSS_INFO+aAYN%AYN@MCIMAIL.COM

©1994, ROSS Technology, Inc. Sun, the Sun logo, Sun Microsystems, SunSoft and Solaris are trademarks or registered trademarks of Sun Microsystems, Inc. All SPARC trademarks are trademarks or registered trademarks of SPARC International, Inc. hyperSPARC is licensed exclusively to ROSS Technology, Inc. SPARCstation and SPARCserver are licensed exclusively to Sun Microsystems, Inc. Products bearing SPARC trademarks are based upon an architecture developed by Sun Microsystems, Inc. All other product or service names mentioned herein are trademarks of their respective owners.

CIRCLE NO. 125



Wherever you want to take wireless personal communications, we can help you get there.

Expand your horizons. Talk to a company that offers more routes into the wireless world than anyone else.

A company that has developed complete chipsets and discretes for every major standard. AMPS/(E)TACS, DECT, GSM, POCSAG–you name it.

A company with global R&D resources. A company that's built up unrivalled low-voltage know-how. A company that has unveiled the world's first single-chip baseband digital signal processor for GSM.

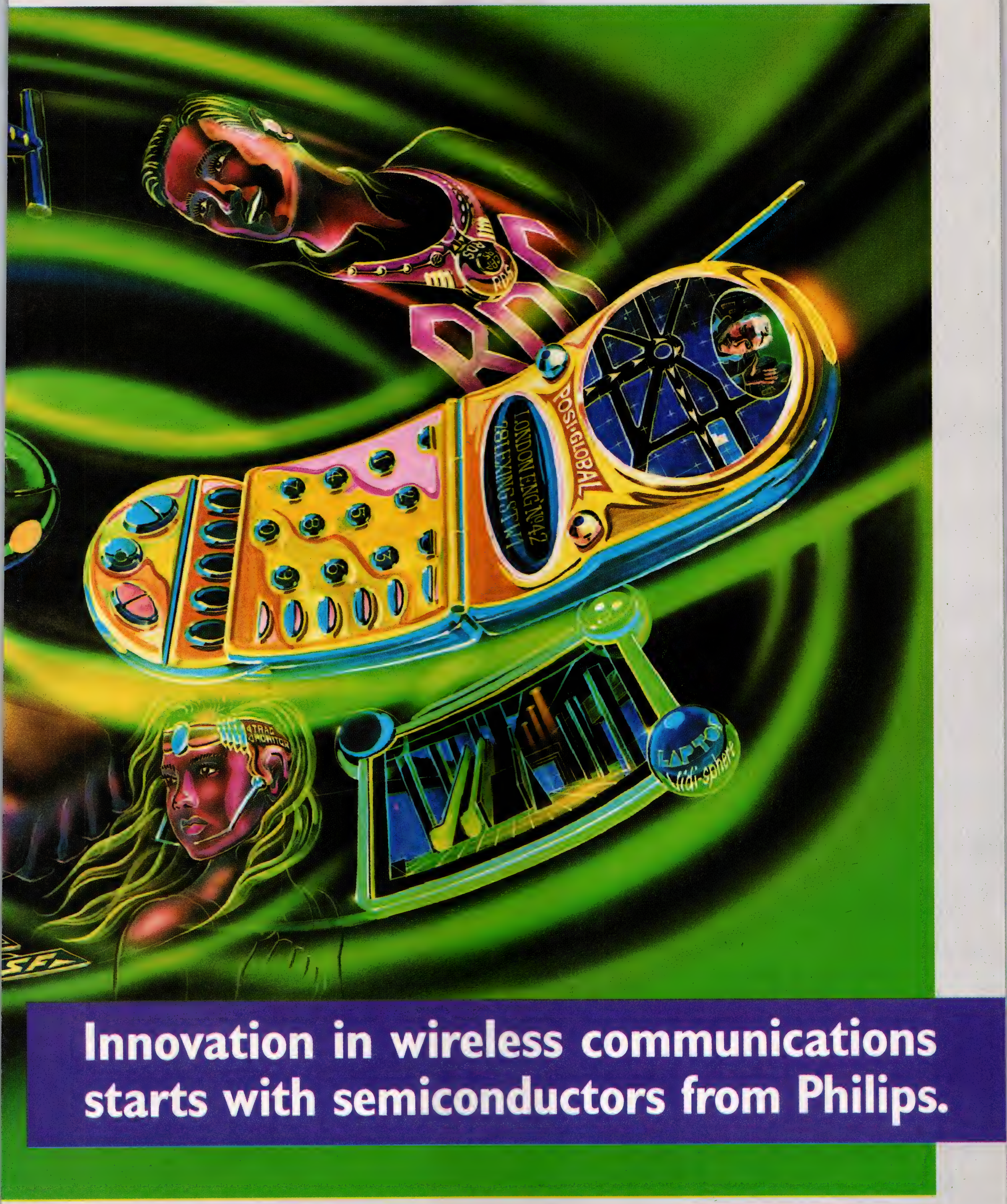
A company that's packing more performance on chip, with technologies like QUBiC and SACMOS. Plus the state-of-the-art C100.

All backed by worldwide application support to help you get your most innovative designs off the ground.

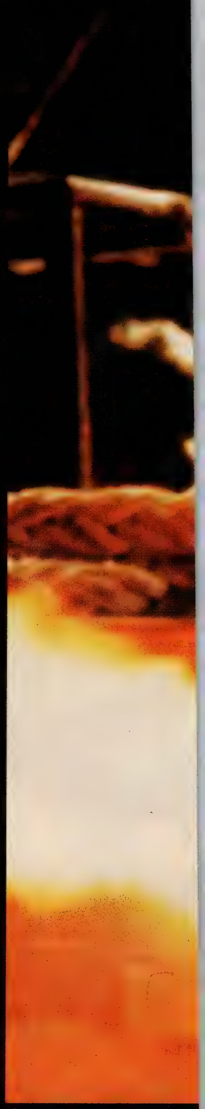
To find out more, see our new Briefing on semiconductors for wireless personal communications. Contact Philips Semiconductors at the number below and we'll send you a copy.

USA, call: 1-800-447-1500, extension 1152.
Europe, fax: +31-40-724825, ask for WPC.
S.E. Asia, fax: +886 (2) 382-4485, ask for WPC.

Philips
Semiconductors


RDS
POSI-GLOBAL
LAPTOP
vidi-sphere
Innovation in wireless communications starts with semiconductors from Philips.

PHILIPS



Shooting down the True Lies in FPGA synthesis benchmarking

To the casual observer, benchmarking FPGA-synthesis software seems a dull and predictable step in evaluating any software package. Yet under the surface you will find more drama than in the movies.

JOHN COOLEY,
EDA CONSUMER ADVOCATE

In the movie *True Lies*, Arnold Schwarzenegger plays a software salesman who, secretly, is a sort of James Bond-with-muscles super spy. Although his movie wife thinks her movie salesman/husband leads an extremely safe and predictable life, in "movie reality," he shoots bad guys, ducks explosions, and strongarms his way out of situations that seem only to happen in, well, the movies.

In real life, the FPGA-synthesis world is going through its own version of *True Lies*. Companies such as Synopsys put "Wrath-of-God" clauses in their licensing agreements if you benchmark their tools. When discussing benchmarking at DAC, Cadence CEO Joe Costello was uncharacteristically quiet in front of a large audience. PREP's synthesis benchmarking group WG-4 gets negative press in *EE Times* from the likes of Xilinx and Altera for proposing how to do a synthesis benchmark. *And this is just what goes on in public!*

Why all the conflict? After all, you can get critical information about a $7 movie via newspaper reviews and ratings; it makes sense that you should be able to get as much information about a $30,000 software package. But not so...Many EDA vendors view benchmarks as something more like *benchmarketing*. With benchmarks, the market leaders see their worst fears becoming real: some small company (with nothing to lose) comes up with a slightly better tool that threatens a leader's market share. Or, just to make things worse, the small company's tools are actually not any better—but manage to appear better in some contrived, yet very public, benchmarks.

At the heart of EDA vendors' fears over benchmarking is an assumption that customers will drop everything to flock to the current benchmark winner, which is simply unrealistic. But, then again, when you're dealing with fears, people can be unrealistic. Customers buy EDA tools for a variety of reasons, most of which have little to do with the speed or efficiency of the tool itself. In this report, you'll see a mixed approach towards how to benchmark an FPGA-synthesis tool as well as the complexities involved. In your reading, whether

an EDA customer or EDA vendor, keep in mind the following:

- All bets are off in any benchmark once revisions change in the software. A lot can, and often does, happen with revisions, thus invalidating prior comparisons.
- Customers don't jump from tool to tool because there's a serious learning curve or price barrier involved. Being an "expert" with one tool can achieve far better results than being a "newbie" in a currently hotter tool. (By the way, who's got the budget to buy the hot tool du jour?)
- Customers should keep in mind that all software has bugs, unexpected issues, and "gotchas"; what's important, however, is how your EDA vendor forewarns you about bugs and how the vendor responds to the bugs you find. Can you get the vendor's technically sharp people on the phone after you've bought the tool? How about other knowledgeable customers? Do you have access to outsiders' critical feedback on the tool? Many times, unofficial help is the best help around.
- FPGA synthesis is primarily around to help finish your FPGA design quickly. It's software aimed at shortening your design cycle. If you want perfect designs, hand pick and place every gate via a schematic-capture package. It may take months to do what synthesis does in days, but it will be better! For those who don't have copious free time to complete designs, look into synthesis.
- For the most part, no real-world designs were used in these benchmarks; that is, dual instances of the standard nine PREP benchmarks (which weren't created with synthesis in mind) were used. As a result, there's a serious design flaw in these benchmarks, because many synthesis tools don't shine in simple, single, small design instances but in the act of sewing together these instances in one final design.

In the following five mini-articles, please note some of the complexities involved with benchmarking FPGAs and FPGA-synthesis tools. I interviewed more than 120 individuals for this article and examined approximately 30 benchmarks. The bulk of interviewees came from engineers responding to a query via hardware-design-oriented Internet newsgroups and e-mail lists.

As EDA consumer advocate, my goal in writing this article is two part. First, I want to educate EDA consumers concerning the complexities of benchmarking FPGAs and FPGA-synthesis tools. Second, I want to desensitize some of the slightly paranoid EDA vendors (along with a few of their FPGA-vendor "technology partners") concerning their horror at watching their products go through independent benchmarking.

A caveat to readers: If you *still* think you can glean from this article which FPGA-synthesis tool is currently the best, think again! Too much depends on FPGA architectures, experience of the tool user, place-and-route tools, and HDL coding styles. Also, hidden-agenda benchmarks confuse the issue even further. This is not to say that objective FPGA-synthesis benchmarks are impossible—it's just that they'd be both politically and technically ugly.

BENCHMARKING SYNTHESIS ON FINE-GRAINED VS COURSE-GRAINED ARCHITECTURES

"Before my company went through the process of internally qualifying and promoting specific brands of FPGAs, they wanted me to do an in-depth study of how synthesis deals with fine-grained and course-grained architectures," says Engineer X, who performed this benchmark. "Of course I want to remain anonymous because I don't want to deal with hysterical FPGA and FPGA-synthesis vendors—or their lawyers."

For this study, Mr X tried to choose FPGAs he thought were closest to what were typical fine- and course-grained chips. For fine-grained, he chose Actel's ACT1020, QuickLogic's QL12x16, and Atmel's AT6005; for course-grained, he selected Altera's EPM7256, Lattice's pLSI1048, and AMD's MACH210.

"And just to confuse matters, most FPGA vendors offer a variety of freebies to their chips, making most of them weird hybrid fine-/course-grained architectures. For example, Altera has Expander product terms, which are freely allocatable logic resources that provide an element of small-grained function to a generally course-grained architecture. AMD's MACH family also has product term allocation that effectively lets the designer steal product terms from one macrocell to another—making one cell fine-grained and another course-grained! Typically, fine-grained elements have a small fan-in, and large-grained elements have a large fan-in. Yet QuickLogic has wide-input AND gates feeding an essentially fine-grained logic element," says Engineer X.

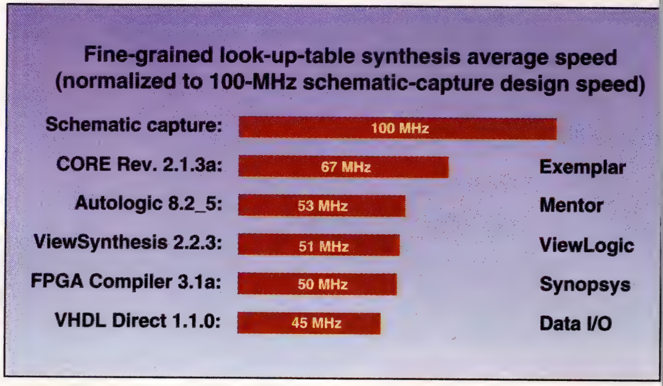
ENGINEER X:

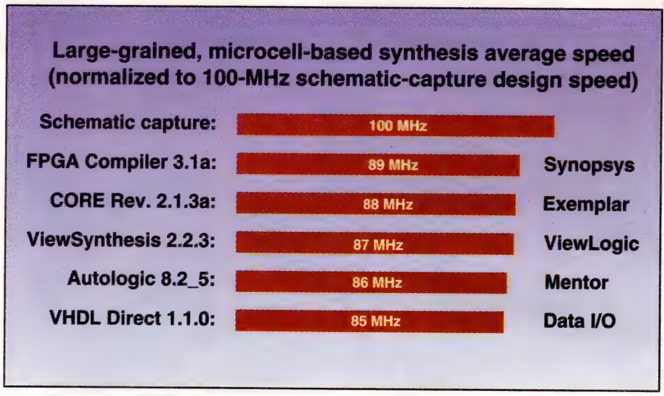
"Coming to general conclusions about area tradeoffs is so architecture-dependent that it's not worth trying."

"Also, there are architectural freebies that have no impact on granularity but make it hard to compare area usage. Xilinx has long lines driven by tri-state buffers that can be used to implement cheap wired AND functions to replace a MUX. Both Xilinx and Altera include Carry-Look-Ahead functions inside basic building blocks. Both companies also have dedicated clock enable signals, which would otherwise use a complete MUX to emulate that function. This list of area-saving features for very specific situations is endless. It makes coming to general conclusions about area tradeoffs so architecture-dependent that it's not worth trying," reports Engineer X.

Using dual instances of all nine PREP benchmarks, Engineer X concludes:

- FPGA synthesis cannot beat FPGA schematic-capture-based designs in either area or speed—regardless of FPGA granularity. But to get a design completed quickly, synthesis is far quicker than schematic capture.
- Fine-grained, look-up-table-based architectures synthesize to roughly 50% the speed of schematic-capture designs on the same FPGAs.
- Large-grained, macrocell-based architectures synthesize to approximately 85% the speed of schematic-capture designs on the same FPGAs because the large-grained designs completely mapped to two level AND/OR/INVERT structures. All extra logic is built in parallel—making it fast, but large.
- Some synthesis tools are far more involved to master than others.
- On average, when creating synthesis-based designs, 50% more "area" is burned up compared with schematic-capture-based designs. This figure, however, can vary 10 to 100% depending on the FPGA, the experience of the synthesis user, and how savvy a schematic designer is.
- Most important, the back-end postsynthesis technology mapping and fitting tools have an extremely large impact on final FPGA speed and area. Varying Verilog and VHDL coding styles also have an impact on synthesis results.





BENCHMARKING: THE TECHNOLOGY MAPPER CHANGES EVERYTHING

"Because our FPGAs are designed to be speed critical, our attention is on our customers' getting the fastest designs possible," says Bill Falk, director of software at QuickLogic. "Because current FPGA-synthesis tools aren't up to squeezing out that last bit of speed, we focus a lot of energy into postsynthesis technology mapping to get the best performance possible."

Falk's benchmark compares five commercial FPGA synthesizers by using two instances of each of the nine standard PREP benchmarks before and after QuickLogic technology mapping. "We have two postsynthesis FPGA tools the customer could use:

Bill Falk, **QuickLogic's director of software:** *"It's important to think of commercial FPGA-synthesis tools as something you buy to couple with a specific FPGA technology mapper."*

the technology mapper or the simple packer," says Falk. "The output of synthesis tools is typically a netlist of fine-grained two- and three-input logic gates to represent the synthesized design. The technology mapper has built-in algorithms for localized logic optimization, packing multiple gates into each logic cell as densely as possible. It factors common subexpressions implemented in QuickLogic-specific AND gates that serve as select lines to the QuickLogic-specific 4-to-1 multiplexer. The technology mapper makes it possible to implement complex functions, such as the following, in a single QuickLogic macro cell:

(a&!b&c&(!d XOR d&!e&!f&g)) XOR (e&!f&g XOR d).

The technology mapper usually changes the entire postsynthesis netlist. In contrast, the simple packer does no logic optimization whatsoever. The packer also leaves all netlists as they were before packing; it just blindly packs what the FPGA-synthesis tool outputs into the QuickLogic target FPGA," says Falk.

The impact of technology mapping can be rather dramatic; this process can almost completely reverse the relative rankings of FPGA-synthesis tools. Take time to examine the tables on this page: you'll find that Synopsys uses 60% less area, on average, after technology mapping. Synopsys experiences a 37% improvement in the speed domain after technology mapping. For both area and speed, Synopsys ranked fourth *prior* to technology mapping and then jumped to second place *after* technology mapping. In contrast, Innovative Synthesis Technologies (IST) AsylPlus has QuickLogic-specific libraries in the synthesizer but didn't do as well in the final results.

Bill Cox, QuickLogic's CAE tools architect, and Venkatesh Nathamuni, QuickLogic's third-party tools manager, comment on the disparity in results: The reason QuickLogic's technology mapper has higher impact on Synopsys designs than IST AsylPlus designs is due to the fact that Synopsys writes its synthesized netlist purely in terms of simple two- and three-input gates, which the technology mapper can easily collapse and optimize. IST AsylPlus, on the other hand, uses a combination of QuickLogic library gates and some simple gates to technology map its synthesized design. As a result, the synthesized netlist from IST AsylPlus has a mix of coarse-grained and simple two- and three-input gates. When QuickLogic's technology mapper runs on this IST synthesized netlist, it can improve the implementation only on the simple two- and three-input gates, thereby having a smaller impact on IST AsylPlus designs.

Cox and Nathamuni also say that Synplify-Lite, like IST AsylPlus, uses a combination of coarse- and fine-grained gates in its synthesized netlist. Synplify differs from IST AsylPlus in that its coarse-grained gates are extremely well optimized for the QuickLogic architecture compared with IST AsylPlus gates.

RELATIVE AVERAGE POSTSYNTHESIS CELL UTILIZATION OF PREP BENCHMARKS

(NORMALIZED TO BEST CELL UTILIZATION AFTER TECHNOLOGY MAPPING)

Area ranking using the QuickLogic Packer, which does *no optimization:*

AsylPlus v3.0.4	1.84	(IST)
CORE v2.1.4	1.93	(Exemplar)
Synplify-Lite v2.0	2.15	(Synplicity)
FPGA Compiler v3.0a	2.93	(Synopsys)
ViewVHDL v2.2	3.02	(ViewLogic)

Area ranking after using the QuickLogic Technology Mapper, *which handles area and speed architecture-specific optimization:*

Synplify-Lite v2.0	1.00	(Synplicity)
FPGA Compiler v3.0a	1.15	(Synopsys)
AsylPlus v3.0.4	1.39	(IST)
CORE v2.1.4	1.43	(Exemplar)
ViewVHDL v2.2	1.60	(ViewLogic)

Note: An example relative ranking is Exemplar's CORE v2.1.4, which used 43% more cells after technology mapping and 93% more cells prior to technology mapping than did Synplicity's Synplify-Lite v2.0 after technology mapping.

RELATIVE AVERAGE POSTSYNTHESIS CRITICAL PATHS OF PREP BENCHMARKS

(NORMALIZED TO HIGHEST SPEED DESIGN AFTER TECHNOLOGY MAPPING)

Speed ranking using the QuickLogic Packer, which does *no optimization:*

Synplify-Lite v2.0	1.32	(Synplicity)
CORE v2.1.4	1.38	(Exemplar)
AsylPlus v3.0.4	1.59	(IST)
FPGA Compiler v3.0a	1.66	(Synopsys)
ViewVHDL v2.2	2.18	(ViewLogic)

Speed ranking after using the QuickLogic Technology Mapper, *which handles area and speed architecture-specific optimization:*

Synplify-Lite v2.0	1.00	(Synplicity)
FPGA Compiler v3.0a	1.05	(Synopsys)
CORE v2.1.4	1.35	(Exemplar)
AsylPlus v3.0.4	1.53	(IST)
ViewVHDL v2.2	1.62	(ViewLogic)

Note: An example of relative ranking is ViewLogic's ViewVHDL v2.2, which had a critical path delay 62% longer after technology mapping and 118% longer prior to technology mapping than did Synplicity's Synplify-Lite v2.0 after technology mapping.

Bill Falk interjects, "Renaming a gate-oriented ASIC-synthesis tool to be an FPGA-synthesis tool just doesn't cut it. Most early synthesis R&D centered around gate-oriented synthesis for ASICs. We had to compensate by making a rather powerful technology mapper. Synplify was designed from the ground up to work well with QuickLogic's FPGAs—it's not just another port of MIS or SIS. (MIS and SIS are two public-domain synthesis tools from Berkeley that are widely used by commercial synthesis vendors as a starting point for development.) That's why Synplicity did well in our benchmarks and that's why we cut a deal with Synplicity to OEM its synthesizer.

"It's important to think of commercial FPGA-synthesis tools as something you buy to couple with a specific FPGA technology mapper—miss this, and you miss more than half the story!" concludes Falk.

BENCHMARKING THE BASIC QUALITY OF PC-BASED FPGA-SYNTHESIS SOFTWARE

"Why bother trying to compare the synthesis efficiency of FPGA-synthesis tools with benchmarks when many of these tools are poorly written software products in the first place?" asks Nick Schmitz, AMD's PLD product planning manager, whose task is to check the basic quality of commercial FPGA-synthesis tools. "I'm not trying to compare whether one tool creates a better up/down counter than another tool using AMD's MACH FPGAs; I'm trying to duplicate what customers go through in using these tools, so the customer can *just use* the tools. I spend a lot of time finding bugs, irregularities, and unexpected results using FPGA-synthesis tools and then reporting them to the FPGA synthesis vendor."

In benchmarking the quality of PC-based FPGA-synthesis tools, Schmitz has three PCs on his desk—and access to more if necessary. His primary workhorse is a 66-MHz Cube DX266 with 16-Mbyte RAM and a 500-Mbyte hard disk. He sometimes runs the software on a laptop PC just to have a different machine run the software. (For this project, all data refers to the 66-MHz, 16-Mbyte RAM Cube unless otherwise noted.)

Nick Schmitz, AMD's PLD product planning manager: *"Funky and multiple flavors of VHDL, bugs, and lack of clean interfaces with other software tools haunt pc-based FPGA-synthesis tools."*

For this evaluation, Schmitz used a test suite of 35 designs written in VHDL from a variety of sources: three complete sets of dual-instanced PREP 1.2 benchmarks from Data I/O, IST, and Xilinx; five demo examples from ViewLogic, including a 2901 and a BCD decoder; and miscellaneous design examples from Synopsys tutorials, various text books, and some AMD engineers. Schmitz' basic criteria while using the tools included

- Product installation and CPU resources required for FPGA synthesis
- Acceptance and understanding of full 1076 VHDL syntax
- Insensitivity to "typecasting" (ie, Can a Boolean feed a bit? Don't want strict typechecking for synthesis, etc)
- Effective use of PC memory
- Direct mapping to AMD's MACH family of AND/OR/INVERT macros, asynchronous sets and resets, latches, D&T flip-flops, tri-states, input registers, and latches
- Software-bug frequency
- Error-message clarity and problem diagnosis
- Hotline access to skilled support staff and resources.

RANKING OF PC-BASED FPGA-SYNTHESIS TOOLS

Best: VHDL Direct v1.1.0 (Data I/O, Metamor)
Good: CORE v2.1.5 (Exemplar)
Fair: ViewSyn v5.1.1 (ViewLogic)
Needs help: AsylPlus v3.0.4 (preproduction alpha code) (IST)
Note: Synopsys, Mentor, Cadence, and Minc are not represented because all are Unix-workstation-based tools. Altera's proprietary PC-based FPGA-synthesis tool was not evaluated because it does not support AMD's MACH family.

The reasoning behind the ranking:

Data I/O's VHDL Direct (1.1.0)

"Data I/O's VHDL Direct (v1.1.0) is a robust FPGA design system that's well targeted to AND/OR/INVERT CPLD structures. It handles a range of varying VHDL syntaxes and gives results after a rather short CPU run time. It uses the PC's 16-Mbyte memory rather efficiently with only one out of 35 test designs encountering an out-of-memory condition," says Schmitz.

Schmitz continues, "Each of the PREP benchmarks I used intentionally has two instances of each benchmark design. Unlike some of the other tools evaluated in this project, VHDL Direct was smart enough to recognize two instances of the same logic and optimized only one—it didn't duplicate the effort." It also gives the customer a factoring control mechanism where you can tell the tool to use N-bit-wide gates preferentially. Thus, if you want higher speed, you use wider gates at the expense of area. If you want less area, opt for narrow gates at the expense of speed. You can fine tune for your particular design down to the exact bit width.

"The drawback with this tool is that it isn't a Windows program but a DOS-based tool. Earlier bugs in v1.0.0, such as not being able to handle 1164's nine value variable declarations, have been fixed in this revision. It doesn't support gate-array or fine-grained FPGA design," states Schmitz. "VHDL Direct has a custom fitter for AMD MACH chips."

Exemplar's CORE v2.1.5

Exemplar's CORE v2.1.5 is a complex of Windows software, supporting many FPGA and gate-array libraries. The tool has only two user switches: "-area" and "-fast." It uses a multiple-pass approach to synthesis, with the user watching the results on a graph. "My test suite of 35 designs garnered runtime results and memory requirements that were significant for the PREP state machine and arithmetic functions. One arithmetic function (PREP #5) ran out of memory and died in the eighth CORE pass. In 35 test designs, three out-of-memory deaths occurred," says Schmitz.

Schmitz reports that the earlier release of CORE (v2.1.3b) had problems running large state-machine (and some other) designs. One design, for example, ran more than 10 hours with

Motorola Pressure Sensors Keep Growing.

Newest additions to portfolio – 0 to 1.5 PSI, High-Impedance, Low-Pressure Sensors – are ideal for portable, low-power and battery-operated applications.

The pressure keeps building for ever-lower low-pressure sensors for use in low-power and battery-operated equipment, and once again, Motorola has come up with the solution: the MPX7006 and MPX7010 series silicon piezoresistive pressure sensors.

Designed to provide a very accurate and linear voltage output directly proportional to the applied pressure, these devices house a single monolithic silicon die with the strain gauge and thin-film resistor network integrated on each chip. The sensor is laser-trimmed for precise span, offset calibration and temperature compensation. Ideal applications include air movement control, level indicators, controllers and pressure switching.

Pressure Points

- *High Impedance Element Reduces Current Drain to 1.0mA (typ.*)*
- *Temperature-Compensated over 0°C to +85°C*
- *Full Scale Span Calibrated to 25 mV or 40 mV (typ.*)*
- *Unique Silicon Shear Stress Strain Gauge*
- *Easy-to-Use Chip Carrier Package Options*
- *Ratiometric to Supply Voltage*
- *Basic Element, Single and Dual Portal Devices*
- *Differential And Gauge Configurations*

Incredible Growing Portfolio

The addition of the MPX7006 and MPX7010 series pressure sensors make Motorola's portfolio more complete than ever. Other members of the growing family include the MPX7100 and MPX7200 series, which offer all the innovative features of Motorola's MPX2000 series – including the patented, single piezoresistive strain gauge, on-chip temperature compensation and calibration, and a high input impedance of typically 10KΩ. They are ideal for instrumentation and remote sensing with 4-20 mA requirements.

Designed for the same types of applications is the MPX7050 series, on-chip temperature compensated and calibrated, with a high input impedance of typically 10KΩ, an output of typically 40 mV FSS, and with an operating temperature of -40°C to +125°C.

Is Your Interest Growing?

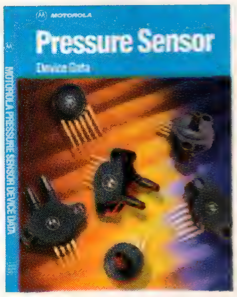
For more information on Motorola's ever-expanding portfolio of silicon pressure sensors, request Pressure Sensor Device Data Book #DL200/D, Rev. 1, by sending the coupon below, by calling 1-800-441-2447, or by writing Motorola Semiconductor Products, Inc., P.O. Box 20912, Phoenix, AZ 85036.

**Actual impedance may vary by device type. Please refer to data sheets.*

MOTOROLA

Motorola and Ⓜ are registered trademarks of Motorola, Inc.

To: Motorola Semiconductor Products Inc., P.O.Box 20912, Phoenix, AZ 85036



Please send me Pressure Sensor Device Data Book (#DL200/D, Rev. 1.)

645EDN102794

Name

Title

Company

Address

City State Zip

Call Me (   )

no results. "I found some problems in syntax dealing with two-phased clocked logic in v2.1.3b that were fixable. In addition, v2.1.3b had a damned-if-you-do, damned-if-you-don't problem in handling declared-variable sensitivity lists. (Incomplete sensitivity lists caused errors; fix the incomplete sensitivity list and other problems developed.) The newer v2.1.5 has similar problems associated with clocks and sensitivity lists, but to a lesser degree," states Schmitz.

CORE v2.1.5 did not recognize the two instances of the same logic in the PREP benchmarks, thus duplicating optimization efforts. The duplication might explain the long runtimes encountered in using the tool.

Support for AMD MACH CPLD is through Minc EDIF because Exemplar doesn't have a MACH fitter yet, working with AMD to develop this.

ViewLogic's ViewSyn (v5.1.1)

Positives: ViewSyn is part of ProSeries (Windows release) for ViewLogic tools. It has links to schematic generation to allow visualization of generated logic, ABEL device fitting, ViewSim simulation, EDIF I/O, etc. It's a complete integrated tool set for FPGA design.

Negatives: The VHDL used here is not 1076-compliant, much less 1164 compliant! Type definitions are the main problem here. Basic four-value logic such as "1," "0," "X," and "Z" has to be represented by VL_BIT instead of the IEEE-standard "bit" and bit_vector. Also there is no type_def support, which compounds the problem. If there were type_def support, "bit" could have been created using the following scrap of VHDL:

```
Package type_def is
        subtype VL_BIT is bit;
end
```

"This basic incompatibility with even rudimentary 1076 VHDL has made porting designs to and from ViewSyn a nightmare. As a consequence, I was restricted to looking at only the company's own specially prepared (and carefully pretested) examples. Obviously, the examples went well, but they served as little real test of the tool. It was frustrating to be kept so blind to the tool's functionality because of this odd unportable VHDL. Of the 35 designs in my test suite, only the five special ViewLogic designs worked," reports Schmitz.

IST's AsylPlus v3.0.4

IST's AsylPlus (v3.0.4) is a very early precommercial release of a program that was a component in Actel's ALS for years. It's similar in concept to Exemplar's tool set but soon will be bundled with a fitter for MACH CPLD technology. This early version has bug problems with the test-suite designs by not giving results and running out of memory. It displayed fundamental problems with elementary VHDL syntaxes such as typecasting problems: you couldn't mix "bit" with "Boolean," and it had trouble handing product terms on an FF reset.

PREP #2 (Timer/Counter) and PREP #3 (Small State Machine) didn't work at all because what AsylPlus synthesized required unavailable resources. PREP #5 (Arithmetic) and PREP #6 (Accumulator) worked. The one big test design that was fairly syntax clean (from IST's point of view) ran out of memory while compiling.

After encountering initial errors, instead of stopping as other tools do, the program keeps parsing and spitting out thousands of error messages.

The interface forced the user to run two different interrelated programs manually—but this problem will be fixed by market time. The second program required the user to fill in lots of blanks; there should have been defaults with a browser to let the user pick and choose.

"Exemplar's dongle from Dallas Semiconductor and the Rainbow Technologies dongle, which ViewLogic and Data I/O use, caused no problems for their tools; IST's Electryon dongle had key problems on the Cube PC but worked on a portable PC; I'm still not sure why," Schmitz says.

"Also, note that what's being evaluated is not production code but alpha code, which always has problems," says Schmitz.

Area/speed benchmarks unrealistic

Schmitz concludes that efficiency for FPGA synthesis is down the road. "Basic tool functionality must be a given before we start measuring which tool is "best." If you look at the ASIC-synthesis model, and if you use Synopsys with a Verilog ASIC library debugged years ago, an expert can expect to repeatedly produce decent-quality ASICs using synthesis and simulation. FPGA/CPLD synthesis, on the most part, isn't there yet. Funky and multiple flavors of VHDL, bad PC-memory usage, bugs, and lack of clean interfaces with other software tools and libraries are all factors that haunt current PC-based FPGA-synthesis tools. Today, the situation remains that you can't always write what you want to write for designs—you have to write what your limited tool allows. You also have to seek out EDA vendors that staff their hotlines with skilled people," says Schmitz.

HIDDEN-AGENDA BENCHMARKS

One of the biggest surprises that came with writing this article was discovering the myriad benchmarks currently available that many customers, FPGA vendors, and EDA vendors pointed out to me. Many of these benchmarks were fairly honest attempts at trying to discern which tool is currently the best one for FPGA synthesis.

However, as I was researching, I received phone calls from a few engineers who could not tell me what they wanted to say from their cubicle offices. So we had to talk after hours from their home phones. It was then that I learned about "hidden-agenda" benchmarks.

John Cooley, EDA consumer advocate: *"Always question who is providing your benchmark information—and why."*

To understand the origins and nature of hidden-agenda benchmarks, first I'll explore some of the shortcomings of current benchmarking efforts. Common complaints heard from the benchmarkers include

- "I don't have enough time to learn all the intricacies of each FPGA-synthesis tool—especially since we're only going to buy one company's tool anyway."
- "I don't care if this tool only does 30% of what the leading tool does—we only have $10,000 in the budget for EDA tools this year." Or, con-

We're in

mode.

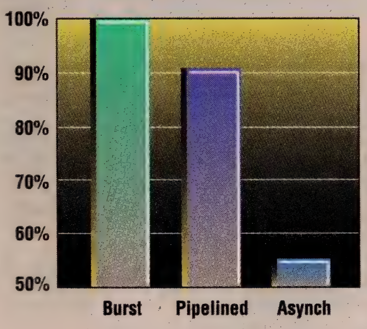
You might say we're bursting with pride. Paradigm is proud to introduce the industry's first family of high-speed, burst mode memories using CMOS technology. A family of 32K x 9, 32K x 18, 64K x 18, and 32K x 36 products that take you to the next generation of high-performance, pipelined or non-pipelined cache memory.

And they enable you to enter the Pentium and Power PC arenas with remarkably efficient and powerful products.

Our patented CMOS process allows our engineers to provide you with some of the highest performance SRAMs around. What's more, our proprietary process is highly scalable, making continued reduction in die size possible. The result? Denser, faster and more desirable products.

So if you're looking to burst on the scene in Pentium or Power PCs, see us first. We'll make it all happen for you. Just a little faster.

L2 Cache Performance vs SRAM Type



PARADIGM

Paradigm Technology, Inc., 71 Vista Montana, San Jose, CA 95134 1-800-767-4530 FAX: 408-954-0664

All trademarks or registered trademarks are property of their respective owners.

CIRCLE NO. 124

versely, "If we don't use up our $30,000 EDA budget by December 31, we won't get it budgeted next year."

- "Let's go with the market leader/the easiest tool to use/the tool with the best hotline or support/the tool that best fits the rest of our EDA tools/the tool with the best sales staff ever to schmooze my management!"

Most of these forces work together not to make most benchmarks objective, across-the-board comparisons of eight EDA tools but, typically, a fistfight between two chosen "favorites." Now office politics rears its ugly head. Upper management buys into one or more of the above arguments and then calls for a "benchmark" to be done, resulting in the following:

- Upper management is insecure. They need to be vindicated! Run the competing tools as stupidly as possible while running the "chosen" tool with tech help from the vendor. "Gosh, management was wise to pick this FPGA-synthesis tool!"
- Upper management wants to be slick and cheap. Make the "chosen" tool look bad in order to use it as a negotiating chip with the EDA vendor. "Gee, we'd love to buy your tool, but it performed poorly in our benchmarks. How 'bout you cut the price by 50%?"
- Upper management doesn't have a clue. Make the tool that you're the expert in look good. That way you're the star! "What's a little job security between friends?"

As a result, although you have plenty of honest benchmarks to rely on, there are also plenty of questionable ones. In short, benchmarks often exist to make FPGA-synthesis vendors look good or bad—depending on political agendas.

One final note: This is not to say that good—and impartial—benchmarks are impossible to create or come by; but be wary, for there are some bad benchmarks floating about, muddying the waters. Always question who is providing your benchmark information—and why.

THE PROS AND CONS OF PREP BENCHMARKS

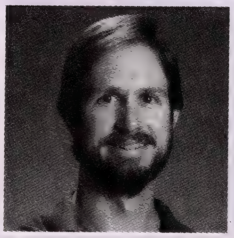
Steve Lass works as a technical marketing manager for NeoCAD, a company that makes place-and-route software designed to compete with proprietary place-and-route software that FPGA silicon vendors sell. As a result, NeoCAD is one of the few FPGA-related companies that can comment on PREP capacity and speed benchmarks for FPGAs with no vested interest in who's currently winning or losing the benchmark race.

NeoCAD has its own internal set of benchmarks to measure FPGA speed and capacity in what it thinks is a smarter way. Steve Lass lists the benefits and pitfalls of PREP benchmarks:

PREP advantages:

⬆ The benchmarks use standard circuits. The type of circuits chosen for PREP seem to be standard and representative subdesigns.

⬆ The results are certified. At least you know someone has looked at the results—and that the data isn't just marketing hype.



Steve Lass,
NeoCAD PREP whiz kid

⬆ The PREP benchmarks take into account utilization instead of "made-up" gate counts. Although a number of issues are involved in the way they determine utilization, it's a lot better than saying 2000 gate-array gates and 4000 LCA gates, etc.

PREP disadvantages:

⬇ The way the circuits interconnect does not reflect reality. It would be really easy to look at a netlist and tell if it is a PREP benchmark because it will generally have 99% of the nets with a fanout of 1 and 1% with a fanout of 100+. Because most parts' speed is relative to the nets' fanout, the benchmark suffers from a large inaccuracy.

⬇ Results rely heavily on the engineer that did the design. PREP defines how the benchmark works but not how it will be designed. I noticed some design shortcuts that Xilinx could have taken, which Altera did, to get better results.

⬇ They show the best possible result you could achieve. You would have to be an expert to get these results. I have the Xilinx XC3000 PREP designs and cannot duplicate the results.

⬇ PREP does not take into account special architecture features, such as fast decoders, tristate buffers, and RAMs, which are not accessed and therefore do not show up in benchmarks.

⬇ PREP's biggest disadvantage is that it does not give an accurate design assessment. Even though many designs will have circuits similar to some of the PREP benchmarks, no one would take 40 16-bit counters and connect them together. Probably not too many engineers would even be willing to take the time the FPGA vendors invested in getting their results.

(Tables and manufacturers listing continued on pg 48.)

John Cooley, an EDA consumer advocate and founder of the outlaw E-mail Synopsys Users Group (ESNUG), lives on the Holliston Poor Farm in Massachusetts. He raises sheep and is an EDA- and ASIC-design instructor and project-in-crisis consultant. He can be reached at "jcooley@world.std.com" or at (508) 429-4357.

VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

High Interest	Medium Interest	Low Interest
583	584	585

Accept no substitutes.

CHOICES. We offer you three distinct families of antifuse FPGAs that provide more than 300 different combinations of speed, density and packaging. So you never settle for less than you need—or pay for more than you want. Also, to ensure you a plentiful supply at competitive prices, we've added Arrow Electronics worldwide to our list of distributors, which in North America includes Pioneer and Wyle.

FAST AND PREDICTABLE. The Actel antifuse is a very low RC interconnect element. And our patented segmented routing offers almost any length of routing track, which minimizes RC for any chosen path. The result is fast, predictable timing, even at high capacities. You get fast logic, such as 167 MHz counters and datapath and 7.5 ns clock-to-out speeds. Which lets you achieve fast designs like 100 Mbit Ethernet receivers, 100 MHz graphics controllers, and 50 MHz DRAM and DMA controllers.

AFFORDABLE. The special combination of the Actel antifuse and channeled architecture gives you the best value in logic today. Our antifuse element is far smaller than competitive switching technologies, delivering greater capacity and more functionality in smaller die sizes. And less silicon equals lower costs. Plus, our channeled architecture lets you use more of the available logic on every chip.

EASY TO USE. Our highly automated Designer Series can cut days, weeks or even months off your design cycle. Our automatic placement and routing tools let you make last minute design iterations with minimal compromises. Recent additions include ACTmap™ FPGA Fitter, a logic synthesis and optimization tool, ACTgen™ Macro Builder, a powerful parameterized macro function generator, and ChipEdit, the first of our new generation of graphical design tools created especially for the Windows™ and X-Window environments. All of which are fully integrated within our core Designer system.

FLEXIBLE. Actel FPGAs and design tools give you the freedom to shrink all or some of your system's logic onto a single programmable device. Only Actel really lets you fix your I/O pins before you've finished your design, so that work can progress on other parts of your system. You get all that, plus high gate utilization, thanks to the plentiful routing resources that are an inherent part of our antifuse technology.

SYNTHESIS FRIENDLY. Our antifuse and channeled architecture give you small, homogeneous logic modules, which make our FPGAs extremely well suited to high-level design techniques such as HDL/VHDL and synthesis. In addition, we've assured that the most popular HDL/VHDL and synthesis tools work with our architecture—including tools from Cadence™, Exemplar, IST, Mentor Graphics®, Synopsys®, and Viewlogic®.

Specify only original, genuine antifuse FPGAs from Actel.

In 1988, we pioneered the first antifuse FPGAs. Since then, we've continued to expand our technology to give you even greater speed, capacity and design flexibility. Today, nobody can match the fast, flexible design of Actel FPGAs because nobody can duplicate our technology. We hold 40 patents on our antifuse and channeled architecture alone.

With microprocessors and memory increasingly standardized, logic design may be the only area where you can differentiate your product. So don't risk your design on anything less than the genuine article: Actel antifuse FPGAs. For information, call 1-800-228-3532. You'll agree, there's no substitute for the real thing.

Actel

955 East Arques Ave., Sunnyvale, CA 94086-4533
1-800-228-3532
908-225-0700 (outside North America)

CIRCLE NO. 148

Table 1—PREP FPGA external-frequencies speed ranking

		PREP benchmark number									
Company	**Device**	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**Min**
Altera	EPM7064-7	95	65	95	58	33	39	95	95	95	33
Altera	EPM7032-7	95	65	95	58	22	39	95	95	95	22
Cypress	CY7C371-143	91	87	91	65	0	50	91	91	91	0
Altera	EPM7096-10	77	52	77	46	25	29	77	77	77	25
Lattice	pLSI1016-110	N/A	74	71	46	23	36	73	73	82	23
Altera	EPM7128-10	77	51	77	46	19	30	77	77	77	19
Intel	FX780-10	80	44	80	31	21	19	80	80	80	19
AMD	MACH210A-10	N/A	44	80	44	19	31	74	74	80	19
Altera	EPM7160-12	63	48	63	40	23	27	63	63	63	23
Altera	EPM7192-12	63	48	63	40	17	27	63	63	63	17
Cypress	CY7C384-2	59	50	40	27	20	90	45	57	37	20
QuickLogic	QL8X12A-3	67	53	44	29	21	31	50	58	43	21
Altera	EPM7064-15	53	40	53	33	18	22	53	53	53	18
Lattice	pLSI1048-80	51	49	47	33	17	24	49	49	50	17
QuickLogic	QL12X16-2	59	50	40	27	20	30	45	57	37	20
Altera	EPF8282-2	58	40	37	16	18	41	54	54	28	16
AMD	MACH230-15	50	29	50	29	13	20	48	48	50	13
Xilinx	XC73108-10	41	23	41	41	24	31	41	41	41	23
Xilinx	3190-3	80	44	39	23	23	29	27	38	21	21
Altera	EPF8452-2	47	36	34	15	17	37	44	45	30	15
Altera	EPF8820-2	51	36	32	15	17	34	44	45	26	15
Altera	EPF81188-2	48	37	32	14	15	36	45	45	27	14
Altera	EPM7128-20	42	29	42	25	12	17	42	42	42	12
Xilinx	XC7272A-16	37	24	37	37	28	23	37	37	37	23
Actel	A1425	50	45	29	20	14	28	40	27	30	14
Altera	EPM7256-2	42	27	42	24	11	17	42	42	42	11
Altera	EPF81500-2	47	30	30	16	14	37	42	42	25	14
Xilinx	4010-5	39	27	26	20	16	26	42	46	28	16
Actel	A1240A-2	35	24	23	17	12	24	32	20	23	12
Xilinx	7272-25	25	20	25	13	13	16	43	25	25	13
Xilinx	3090-125	46	24	24	14	14	17	25	27	13	13
Actel	A1225-1	35	29	21	15	10	20	29	18	21	10
Actel	A1240	30	18	18	13	9	18	24	15	23	9
Actel	A1280-1	30	12	19	14	9	17	21	15	20	9
TI	TPC1280-1	30	12	19	14	9	17	21	15	20	9

Note: N/A=not available.

Table 2—PREP FPGA capacity ranking

		PREP benchmark number									
Company	**Device**	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**Min**
Altera	EPF81500-2	80	45	66	27	34	74	74	74	84	27
Altera	EPF81188-3	62	36	43	19	30	55	55	55	65	19
Xilinx	4010-5	30	30	36	15	25	50	40	40	40	15
Altera	EPF8820-2	41	22	29	12	19	36	36	36	43	12
Actel	A1280-1	48	20	42	18	16	15	25	18	56	15
TI	TPC1280-1	48	20	42	18	16	15	25	18	56	15
Xilinx	3090-125	20	12	20	9	12	20	20	13	20	9
Xilinx	3190-3	20	12	20	9	12	20	20	13	20	9
Altera	EPF8452-3	20	12	15	6	9	18	18	18	21	6
Altera	EPM7256-2	16	9	23	12	6	9	15	15	28	6
Actel	A1240	27	14	23	10	9	8	13	10	31	8
Actel	A1240A-2	27	14	23	10	9	8	13	10	31	8
Altera	EPM7192-12	12	7	17	9	5	7	11	11	21	5
Altera	EPM7160-12	10	6	14	8	5	6	9	9	17	5
Altera	EPF8282-3	12	7	9	3	5	11	11	11	13	3
Cypress	CY7C384-2	12	5	10	5	4	4	8	8	17	4
QuickLogic	QL12X16-2	12	5	10	5	4	4	8	8	17	4
Actel	A1225-1	18	9	15	6	6	5	9	6	20	5
Lattice	pLSI1048-80	12	6	12	9	4	4	6	6	11	4
Altera	EPM7128-20	8	5	11	6	4	4	7	7	13	4
Xilinx	XC73108-10	5	3	10	5	5	5	5	5	10	3
Actel	A1425	10	6	10	4	4	3	6	4	14	3
Altera	EPM7096-10	6	3	8	4	3	3	5	5	10	3
Altera	EPM7064-15	4	2	5	2	2	2	4	4	7	2
QuickLogic	QL8X12A-3	6	2	5	2	2	2	4	4	8	2
Xilinx	XC7272A-16	4	2	8	3	1	4	4	4	8	1
AMD	MACH230-15	6	3	8	4	2	2	4	6	8	2
Intel	FX780-10	5	2	7	3	1	2	4	4	8	1
Xilinx	7272-25	4	2	8	1	1	4	4	4	8	1
Lattice	pLSI1016-110	0	2	4	3	1	1	2	2	3	1
Altera	EPM7032-7	2	1	2	1	1	1	2	2	3	1
Cypress	CY7C371-143	2	1	3	2	0	1	2	2	3	0
AMD	MACH210A-10	0	1	4	2	1	1	2	2	4	0

Avg	Max	Rev	Rank
74	95	1.3	1
73	95	1.3	2
73	91	1.3	3
60	77	1.3	4
60	82	1.2	5
59	77	1.2	6
57	80	1.2	7
56	80	1.2	8
50	63	1.3	9
50	63	1.2	10
47	90	1.3	11
44	67	1.3	12
42	53	1.3	13
41	51	1.2	14
41	59	1.3	15
38	58	1.3	16
37	50	1.2	17
36	41	1.3	18
36	80	1.2	19
34	47	1.3	20
33	51	1.3	21
33	48	1.3	22
33	42	1.3	23
33	37	1.3	24
31	50	1.2	25
31	42	1.2	26
31	47	1.3	27
30	46	1.2	28
23	35	1.2	29
23	43	1.2	30
23	46	1.2	31
22	35	1.2	32
19	30	1.2	33
17	30	1.2	34
17	30	1.2	35

Avg	Max	Rev	Rank
62	84	1.3	1
47	65	1.3	2
33	50	1.2	3
30	43	1.3	4
25	48	1.2	5
25	48	1.2	6
16	20	1.2	7
16	20	1.2	8
15	21	1.3	9
13	23	1.2	10
12	23	1.2	11
12	23	1.2	12
10	17	1.2	13
9	17	1.3	14
9	13	1.3	15
8	17	1.3	16
8	17	1.3	17
8	15	1.2	18
7	12	1.2	19
7	13	1.3	20
6	10	1.3	21
5	10	1.2	22
5	10	1.3	23
4	7	1.3	24
4	8	1.3	25
4	8	1.3	26
4	8	1.2	27
4	7	1.2	28
4	8	1.2	29
2	4	1.2	30
2	3	1.3	31
2	3	1.3	32
2	4	1.2	33

MORE ON FPGA-SYNTHESIS TOOLS AND BENCHMARKING

For free information on FPGA-synthesis tools such as those described in this article, circle the appropriate numbers on the postage-paid Information Retrieval Service card or use *EDN*'s Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN*.

Actel Corp
Sunnyvale, CA
(408) 739-1010
Circle No. 395

Advanced Micro Devices (AMD)
Sunnyvale, CA
(408) 732-2400
Circle No. 396

Altera Corp
San Jose, CA
(408) 894-7000
Circle No. 397

Atmel Corp
San Jose, CA
(408) 441-0311
Circle No. 398

AT&T Microelectronics
Allentown, PA
(800) 372-2447
Circle No. 399

Cadence Design Systems
San Jose, CA
(408) 944-1234
Circle No. 400

Compass Design Automation
San Jose, CA
(800) 433-4880
Circle No. 401

Cypress Semiconductor
San Jose, CA
(408) 943-2600
Circle No. 402

Data I/O
Redmond, WA
(206) 881-6444
Circle No. 403

Exemplar Logic
Berkeley, CA
(510) 849-0937
Circle No. 404

IBM EDA
Los Angeles, CA
(800) 332-0066
Circle No. 405

Innovative Synthesis Technologies (IST)
Danville, CA
(510) 736-2302
Circle No. 406

Intergraph Corp
Boulder, CO
(303) 581-2447
Circle No. 407

Lattice Semiconductor
Hillsboro, OR
(503) 681-0118
Circle No. 408

Mentor Graphics
Wilsonville, OR
(503) 685-7000
Circle No. 409

Minc Inc
Colorado Springs, CO
(800) 755-3742
Circle No. 410

NeoCAD Inc
Boulder, CO
(800) 888-3742
Circle No. 411

QuickLogic
Santa Clara, CA
(408) 987-2000
Circle No. 412

Synopsys Inc
Mountain View, CA
(415) 962-5000
Circle No. 413

Synplicity Inc
Los Altos, CA
(415) 961-4962
Circle No. 414

Texas Instruments
Dallas, TX
(214) 644-5580
Circle No. 415

ViewLogic Systems
Marlborough, MA
(508) 480-0881
Circle No. 416

Xilinx Inc
San Jose, CA
(408) 559-7778
Circle No. 417

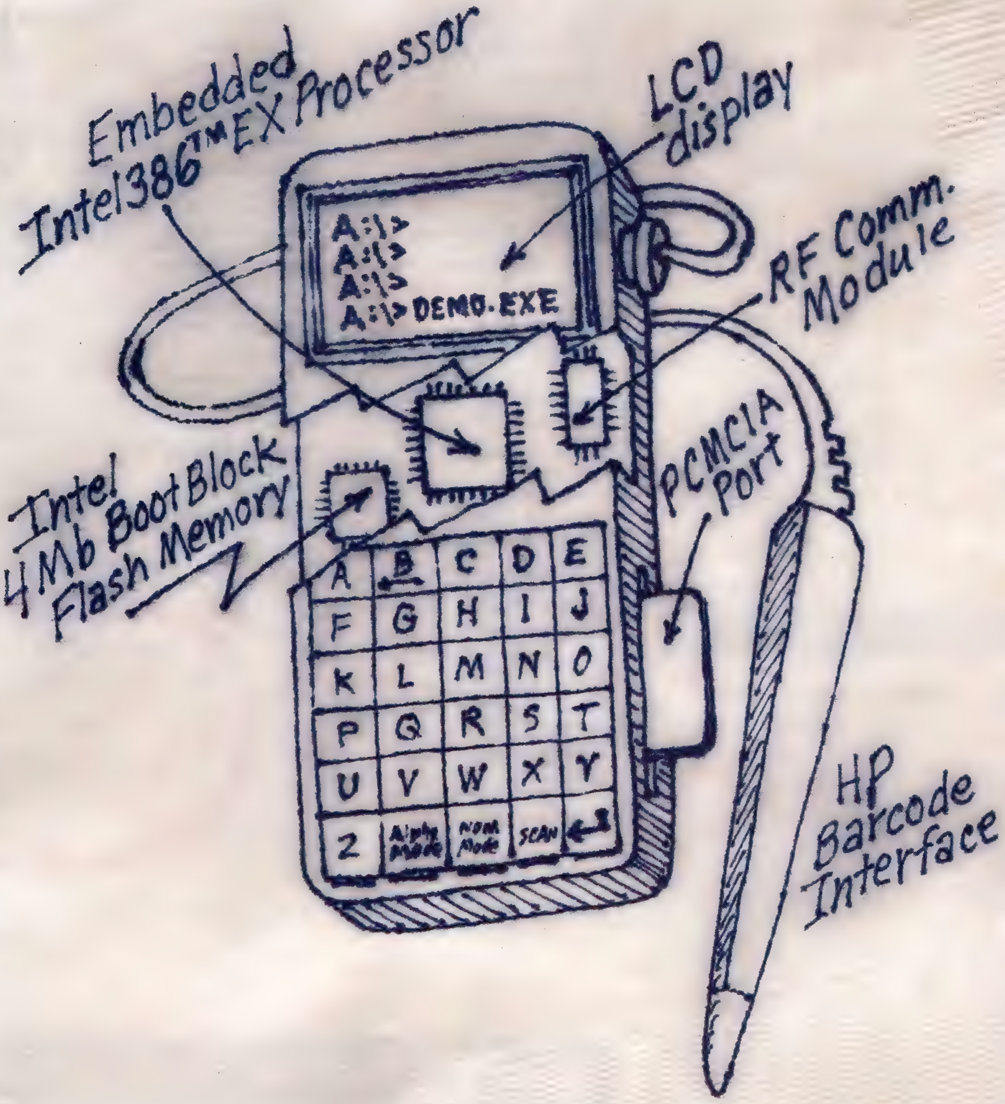
VOTE . . .
Please also use the Information Retrieval Service card to rate this article (circle one):
High Interest 583
Medium Interest 584
Low Interest 585

Super Circle Number

For more information on FPGA-synthesis tools available from all of the vendors listed in this box, you need only circle one number on the postage-paid reader service card.
Circle No. 418

QUICKIE PREP-BENCHMARK DESCRIPTIONS

PREP#1:	8-bit MUX/REG/Shift-REG data path
PREP#2:	8-bit loadable up-counter
PREP#3:	8-state 13-transition state machine
PREP#4:	16-state 40-transition state machine
PREP#5:	4-bit multiply/accumulate
PREP#6:	16-bit resettable accumulator
PREP#7:	16-bit loadable up-counter with asynchronous reset
PREP#8:	16-bit fully synchronous loadable counter
PREP#9:	memory-map address decoder with bus error



Hamilton Hallmark is an Avnet company

Technology by Intel.

Inspiration by Hamilton Hallmark

Would you be interested in shaving a few months off your next embedded design cycle?

Then you'll be fascinated by the H4T Reference Design Kit. H4T is short for Hamilton Hallmark Hand-Held Terminal. And short is what your time to market will be tomorrow if you call Hamilton Hallmark today.

You see, the H4T is not just an idea on a white napkin. Or even an implementation in a white paper.

It's a working application, centered around the Embedded Intel386™ EX Processor and incorporating Intel Flash Memory and all the other technologies you see called out. Including Hewlett-Packard's SmartWand bar code reader.

The Reference Design Kit comes complete with the schematics, firmware/software implementation details, BOM, data sheets, PCB layout, boot source code and detailed application note on which to base your next enhanced design.

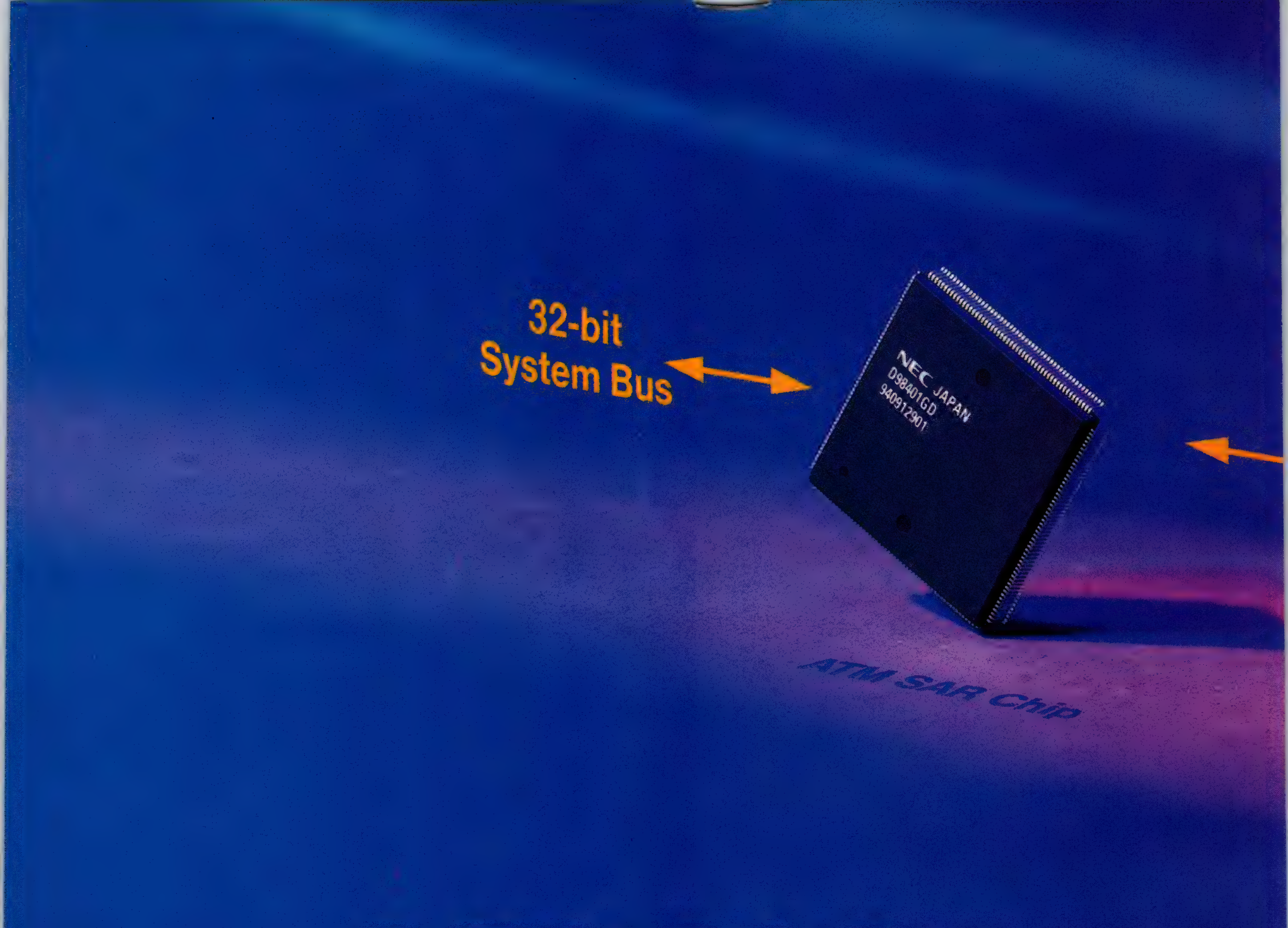
Who initiated the H4T and worked closely with Intel to complete it? The engineers at our Technical Support Center.

The same engineers whose average of 15 years experience in the field makes them so adept at fielding your questions and understanding your problems.

So while it may surprise you to see such an application come from a distributor, the distributor it came from should be no surprise at all.

FOR A FREE H4T
WORKING APPLICATION
REFERENCE DESIGN KIT,
CALL 800-608-3434
TODAY.

HAMILTON HALLMARK



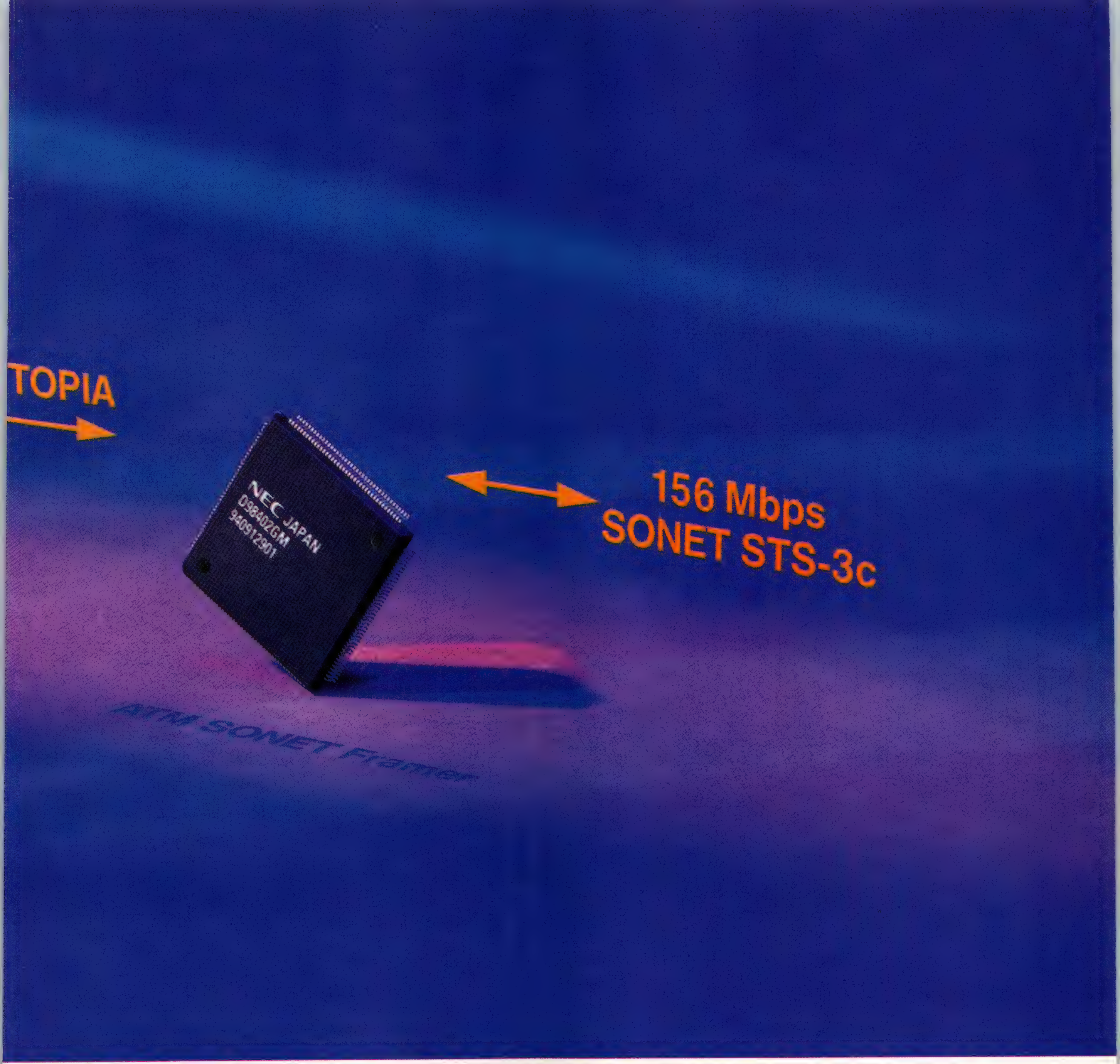
2-Chip Solution Simplifies ATM Design

Off-the-shelf samples available now

NEC's two-chip ATM solution can put you on the fast track to new opportunities in multimedia LAN and WAN markets. Our chipset covers the ATM protocol from the ATM adaptation layer to the physical layer. It simplifies system design, reduces component count and saves board space. It allows you to add ATM capabilities to network equipment such as PCs, workstations, servers, hubs and routers. It's also ideal for ATM network interface cards.

Our ATM SAR chip handles all processing for the ATM Layer. It also supports the Segmentation and Reassembly in the ATM Adaptation Layer (AAL). The chip fully supports AAL5 and assists AAL1 and AAL3/4 for voice, video and data transmission.

Our ATM SONET framer supports the Transmission Conver-



gence sublayer and SONET in the physical layer. It performs high-speed data transmission with a 156Mbps (SONET STS-3c) serial interface and 19.44MHz parallel interface.

Advanced features of NEC's two-chip ATM solution:

☐High-performance DMA controller for easy connection with popular 32-bit buses such as PCI, APbus and Sbus.

☐Extensive 32K virtual-connection support.

☐16 traffic shapers controlled by dual leaky bucket algorithm using peak rate and average rate parameters.

☐UTOPIA-based interface between ATM and physical layers.

☐Ample operation and maintenance functions for performance monitoring and alarms.

☐Compliance with ITU-TS, ANSI T1S1 and ATM Forum recommendations.

Order your sample today

Call NEC today to order your sample of our advanced ATM chipset. It's a streamlined, off-the-shelf solution that puts you on the fast track to success in ATM LAN and WAN markets.

CIRCLE NO. 66

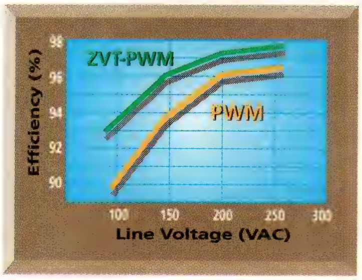
For fast answers, call us at: USA Tel: 1-800-366-9782. Fax: 1-800-729-9288.

NEC

Control Rough Waves with Soft Switching

Reach new heights in power factor correction performance. The UC3855's unique "soft switching" technique dramatically reduces diode recovery and MOSFET turn-on losses. The result is super-high efficiency which enables higher frequency switching and more compact preregulator designs.

Call, FAX or write us today for free samples and application information.



The UC3855 Advantages

- Provides all control functions for Zero Voltage Transition (ZVT) boost PFC
- Soft switching reduces EMI and increases efficiency
- Inductor current synthesizer allows single current sense transformer
- Fixed frequency average current mode control minimizes line current distortion
- Overvoltage and overcurrent protection
- UVLO threshold options
- SOIC and PLCC packages available

INTEGRATED CIRCUITS
UNITRODE

TEL: (603) 429-8610
FAX: (603) 424-3460
7 Continental Boulevard, Merrimack, NH 03054

CIRCLE NO. 107

nsai
I.S./ISO 9001/EN 29001

NEW LCDs REAP BENEFITS OF ACTIVE ADDRESSING

CHRIS CHINNOCK, TECHNICAL MARKETING SERVICES

Active-matrix displays are good but expensive. Passive-matrix displays are cheap but don't perform nearly as well. New LCDs with active addressing are staking out an attractive middle ground.

IF ALL GOES AS PLANNED, A TECHNIQUE KNOWN as "active addressing" will soon dramatically lower the cost of high-quality LCDs. The first commercially available active-addressed LCDs should appear within the next few months, offering performance approaching that of active-matrix LCDs at a cost premium of only 30 to 35% over passive-matrix displays.

Spearheading the coming commercialization of active addressing is Motif (Wilsonville, OR), a company formed in a joint venture between Motorola (Schaumberg, IL) and In Focus Systems (Tualtin, OR), a manufacturer of LCD-based projection products. Several strategic partners of Motif will also market active-addressed displays. Shipments of active-addressed LCDs should begin in the second quarter of 1995 for applications in notebook computers, personal digital assistants (PDAs), and projection products.

Active-addressed LCDs will fill a gap between active- and passive-matrix LCDs. Active-matrix LCDs typically cost twice as much as passive-matrix LCDs, reflecting production complexities and low yields. However, they produce much crisper images than passive-matrix LCDs do, and their faster response rate is adequate for displaying video. Consequently, they are the display of choice for high-end notebook computers. Passive-matrix LCDs, with their slower response and lower contrast images, serve as displays for most other products.

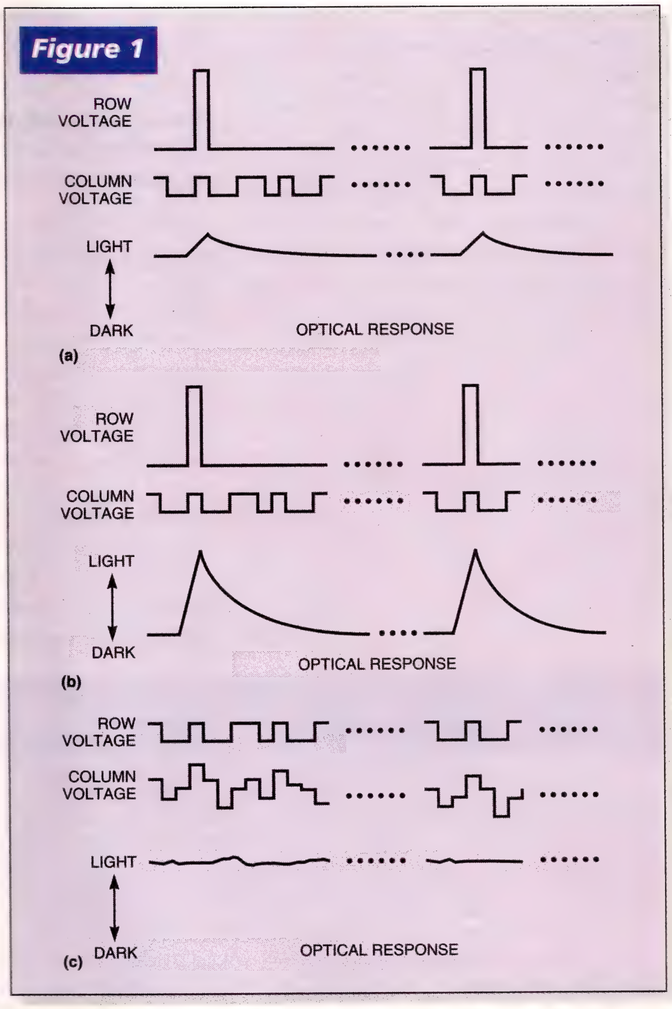
Overcoming limitations

Active-addressed LCDs have the potential for overcoming the limitations of passive-matrix displays for only a modest price increase. Essentially, they refresh pixels more often than passive-matrix displays do, improving image quality.

In passsive-matrix LCDs, a pulse of about 20V amplitude selects one row of pixels at a time; signal voltages on column lines then activate individual pixels. The sequential addressing of all rows occurs over an interval called the "frame time"—16.7 msec for a 60-Hz frame-refresh rate (see **box**, "LCD basics").

The problem with this traditional addressing scheme is that a pixel begins to fade as soon as its address pulse turns off. To improve display brightness and contrast, manufacturers of passive-matrix displays use a liquid-crystal materi-

Figure 1



Most passive-matrix displays use a liquid-crystal material with a slow response (a) to slow image fading. Materials with a faster response (b) can handle rapidly changing images, such as video, but the image fades faster. With active addressing (c), a fast-response material handles quickly changing images, and a modified row- and column-addressing scheme keeps pixels active.

al with a slow response of 150 to 250 msec, thus increasing light throughput over the frame time (**Fig 1a**). This approach is fine for text or static images, but the slow liquid crystal can't respond to faster motions, such as rapid mouse movements, animation, and video. In those situations, images blur or disappear altogether.

Full-motion video requires a pixel response of around 50 msec. Unfortunately, in passive-matrix displays, this faster response results in images that fade quickly (**Fig 1b**). So, although a fast-response display works well for video, it has low transmission and a poor contrast ratio. The problem, however, lies not in the liquid-crystal materials themselves, but in the nature of the addressing scheme.

Active-matrix LCDs improve display quality by using liquid-crystal materials with a fast response and by placing a transistor at each pixel. Active-matrix LCDs provide excellent performance, but fabrication complexity increases their production costs and precludes high yields. A single defective transistor results in a display with a visible flaw. Current estimates indicate that yields are in the range of only 50 to 60%.

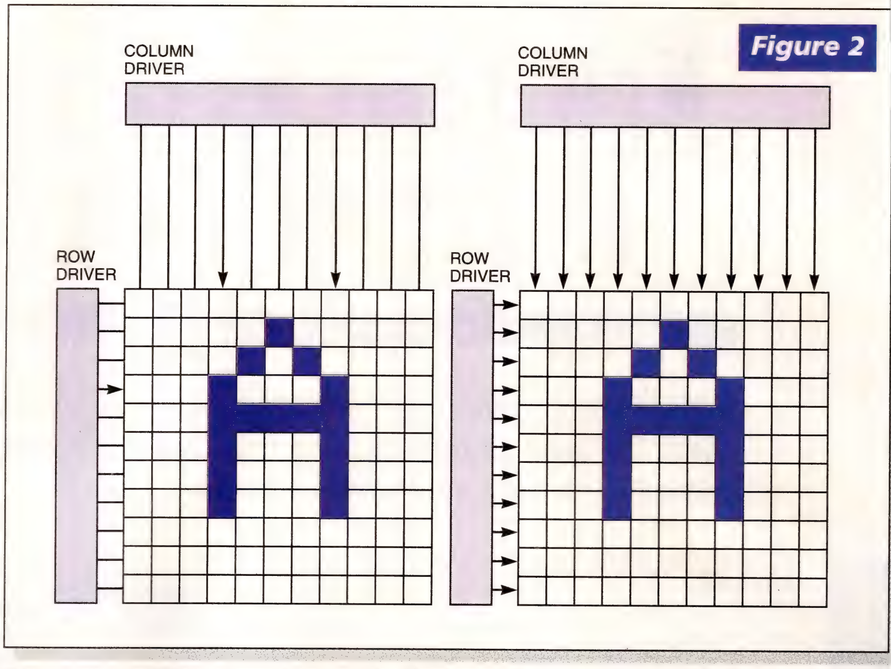
The cost of new, high-volume production facilities—over $500 million for a single plant—also works against active-matrix displays. Nonetheless, the Japanese producers that dominate the market are expanding active-matrix production by adding plants and perfecting a second-generation process. Active matrix is still the technology to beat.

The latest technology, active addressing, uses the lower cost, higher yield processing of passive-matrix production yet, according to Motif, achieves about 90% of the performance of an active-matrix device. Consequently, active-addressed displays offer designers another price-performance point that falls between active and passive displays, where a fairly wide gap exists today. Interface requirements for active-addressed displays are essentially the same as for passive displays.

Active addressing modifies LCDs' conventional row-sequential addressing scheme in favor of a pseudorandom addressing method. A sophisticated mathematical algorithm develops a series of orthogonal row functions that essentially allows near-simultaneous addressing of all pixel rows. This calculation, which is the heart of the active-addressing method, depends upon the image structure of the display information. After frame-by-frame image analysis, small pulses update individual pixels as necessary (**Fig 1c**).

Active addressing can address many rows of pixels over a 2D array in the same time it takes a conventional passive-matrix display takes to address a

Figure 2



Because a traditional passive-matrix display addresses only one pixel row at a time (a), pixels on other rows start to fade. A display with active addressing (b) addresses many rows nearly simultaneously.

LCD BASICS

Passive-matrix displays contain two pieces of glass (substrates), each having parallel lines of transparent electrodes deposited on it. During assembly, liquid-crystal material flows into a small gap between the two substrates. The electrode patterns on the two substrates are orthogonal to each other and form the display's pixel-row and -column address lines. External row and column drivers connect to the display with standard interconnect technologies.

The intersection of voltage signals on row and column lines enables individual pixel addressing. These signals rotate the polarization of incident light so that the light is either blocked or transmitted by a polarizer. With super-twist-nematic (STN) displays, the polarization rotates by as much as 270°.

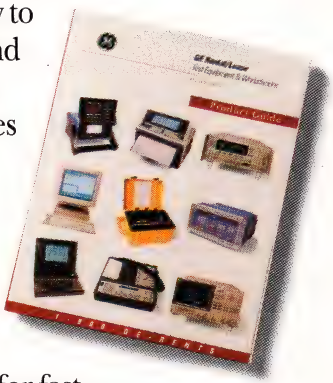
With active-matrix displays, both row and column address lines are on the same piece of glass. In addition, each pixel site has a thin-film transistor (TFT). A storage capacitor associated with each TFT holds the voltage it receives when addressed by the intersection of row and column signals, enabling the TFT to remain turned on throughout the image-frame interval. This ability to better control the light output gives active-matrix displays excellent contrast. It also allows the use of fast-response liquid-crystal material, giving active-matrix LCDs the ability to display full-motion video.

In a color display, each pixel comprises three subpixels. Each subpixel has a red, a green, or a blue filter over it. The eye blends the three subpixel images, which are displayed sequentially in time, to produce a single image point. A standard color VGA display contains almost 1 million pixels (640×480×3).

More Recording Systems than the CIA, KGB and FBI.

Getting the right piece of test equipment shouldn't be as tough as extracting state secrets. That's why GE Rental/Lease has expanded its inventory of recorders and other test equipment available for rent, lease or purchase.

Whatever type recorder you need, from thermal array to DAT tape, you'll find it here, along with 120,000 other pieces of equipment. Name brands like Astro-Med, Gould, TEAC, Yokogawa and more. Easy to find in our new catalog, and ready for fast, overnight delivery.



And all backed by a seasoned team of technical specialists, a quality program registered to ISO 9002 and our exclusive Customer Service Guarantee: *If for any reason you're unhappy with your rental, simply dial 1-800-GE-RENTS and ask for a Customer Service Representative. If we cannot make it right, your rental will be free.*

Now it's no secret where to go for test equipment. Call **1-800-GE-RENTS.**

CIRCLE NO. 34

GE Rental/Lease

Test Equipment & Workstations

A GE Capital Company

single pixel row (**Fig 2**). Consequently, active-addressed displays can use fast-response liquid-crystal materials that can give the displays a near-video response rate. As **Table 1** shows, active addressing improves both the contrast ratio and speed of traditional passive-matrix displays but does not quite match the performance of active-matrix displays.

In an implementation of active addressing, a standard super-twist-nematic (STN) column driver replaces the traditional STN row driver. As **Fig 1a** and **1c** show, the series of smaller voltages pulses replaces the series of larger voltage pulses. An active-matrix column driver also replaces the standard STN column drivers, and additional active-address ICs connect to both row and column drivers. These special ICs contain the algorithms to calculate the address and signal voltages for the display drivers.

Motorola makes the special active-address ICs with standard CMOS silicon-processing techniques, thus keeping the more complex circuitry off the glass panel and making display yields and processes more controllable. Processing and assembly of the two glass panels remain essentially the same as for passive-matrix products. Compared to the processes for active-matrix displays, these processes have fairly high yields, easier design-rule requirements, and reduced plant-capitalization costs. Active-addressed LCDs' 30 to 35% price premium over passive-matrix displays reflects primarily the cost of the special active-addressing ICs.

TABLE 1—LCD PERFORMANCE CHARACTERISTICS

	Active matrix (TN)	**Passive matrix** (STN)	**Active addressing** (STN)
Contrast ratio	50 to 100	15 to 20	20 to 50
Response speed (msec)	50	150	50
Cost relative to passive matrix	2×+	1×	1.2-1.5×
Optical transmission	3 to 7	3 to 7	5 to 6 %
Aperture ratio (%)	20 to 60	80 to 85	80 to 85

Note 1: Typical on-axis performance characteristics for VGA-resolution, 6.5- to 10.4-in. color LCDs. (Data, courtesy of Kahn International, Palo Alto, CA)

To begin supplying active-addressing displays, Motif built a low-volume fabrication facility that opened in November 1993. However, with Japanese companies supplying over 95% of current LCD production, Motif realized that it would also require strategic partners to speed market acceptance of active addressing. Consequently, the company developed agreements with several panel partners, such as Tottori Sanyo (Tokyo), Standish Industries (Lake Mills, WI), Kyocera (Kyoto, Japan), and Optrex (Tokyo). Optrex is an Asahi Glass/Mitsubishi Electric joint venture and the second-largest manufacturer of passive-matrix LCD products.

Motif will provide its panel partners with active-addressing ICs for integration into display products. In return, the partners will give Motif liquid-crystal cells for integration with its ICs. These cells will allow Motif to increase its product offerings to include larger format displays. Most of these agreements will take effect next year.

The new Motif facility can supply about 300,000 displays per year in sizes ranging from 3 to 8 in. (diagonal). However, Motif targets much of its production capacity toward corporate sponsors In Focus and Motorola, which plan to introduce active-addressing projection products and communication devices, respectively, next year.

Motif also plans to address some of the smaller, emerging markets in transportation, industrial, medical, and business. Motif's panel partners, which can supply displays as large as 10.4 in., will aim their products at system integrators in the exploding notebook-computer market, where they will compete directly with active-matrix products.

LOOKING AHEAD

First-generation active-addressing products will feature VGA-resolution (640×480-pixel), reflective and transmissive displays. A second generation of products will have lower resolution (320×480 pixels) and will target the market for personal digital assistants in which lower costs and lower power consumption are necessary. Finally, a third generation of SVGA (1024×780-pixel) and XVGA (1280×1024-pixel) products, 10.5 in. and larger, will address workstations and desktop computers. Manufacturers will begin shipping first-generation products in the second quarter of 1995. Second- and third-generation products should be available as engineering samples in the second half of 1995.

Active- and passive-matrix display products represent a moving target, however. Cost decreases and performance improvements in those technologies will put pressure on the new active-addressed products. Active addressing will also benefit from these technology advances, though, and thus remain a viable middle-ground alternative.

Chris Chinnock is president of Technical Marketing Services in Westport, CT. He can be reached at (203) 226-3947, fax (203) 226-1966.

FOR FREE INFORMATION...

For free information on the active-addressing display products discussed in this article, circle the appropriate numbers on the postage-paid Information Retrieval Service card or use *EDN*'s Express Request service. When you contact manufacturers directly, please let them know you read about their products in *EDN*.

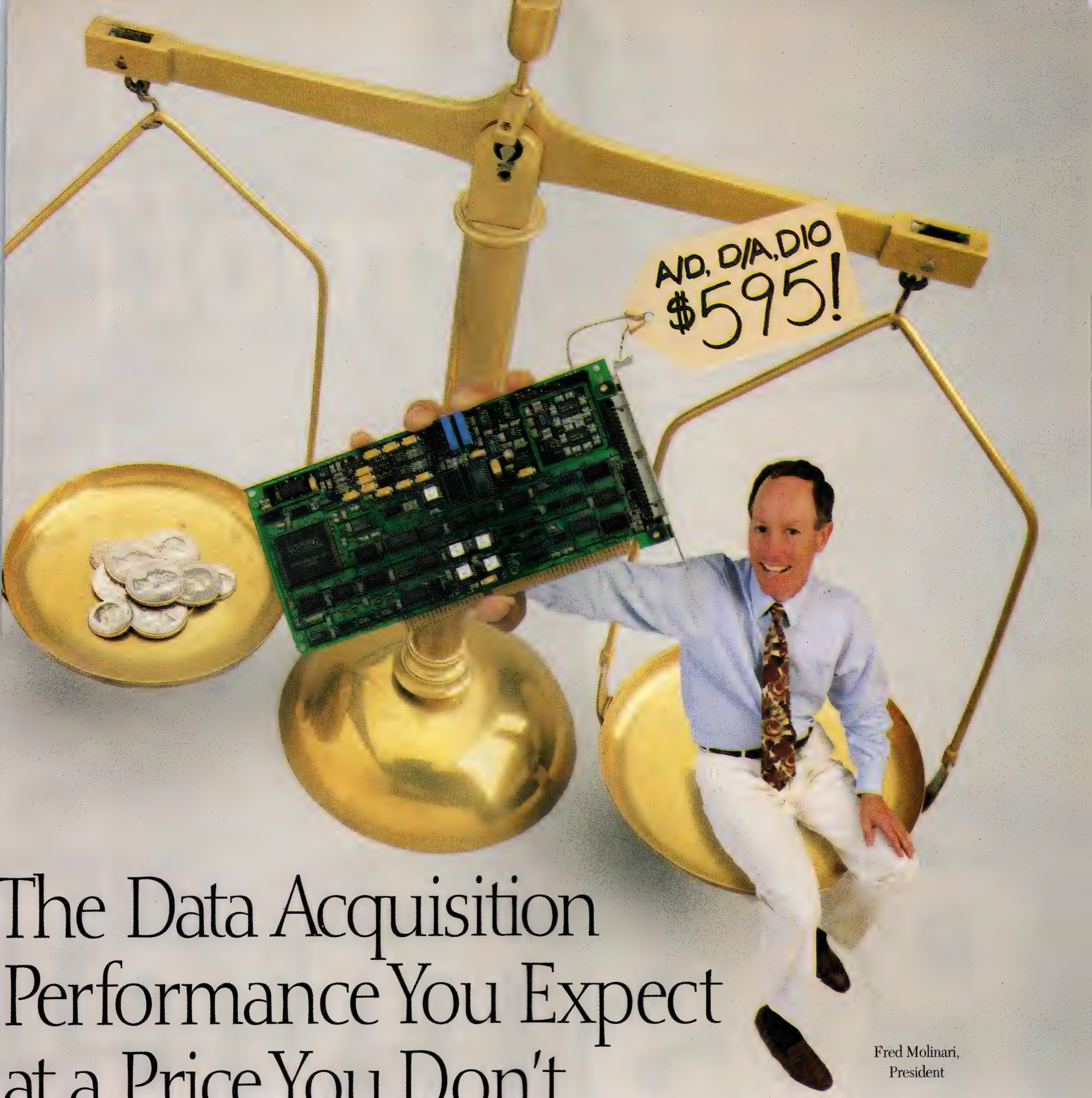
Motif
Wilsonville, OR
(503) 682-7700
Circle No. 301

VOTE . . .
Please also use the Information Retrieval Service card to rate this article (circle one):
High Interest 598
Medium Interest 599
Low Interest 600

VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

High Interest	Medium Interest	Low Interest
598	599	600



The Data Acquisition Performance You Expect at a Price You Don't

Fred Molinari,
President

The industry-leading performance you've come to expect…now at a fraction of the cost. Starting as low as ***$595***, Data Translation has the right data acquisition solution for you.

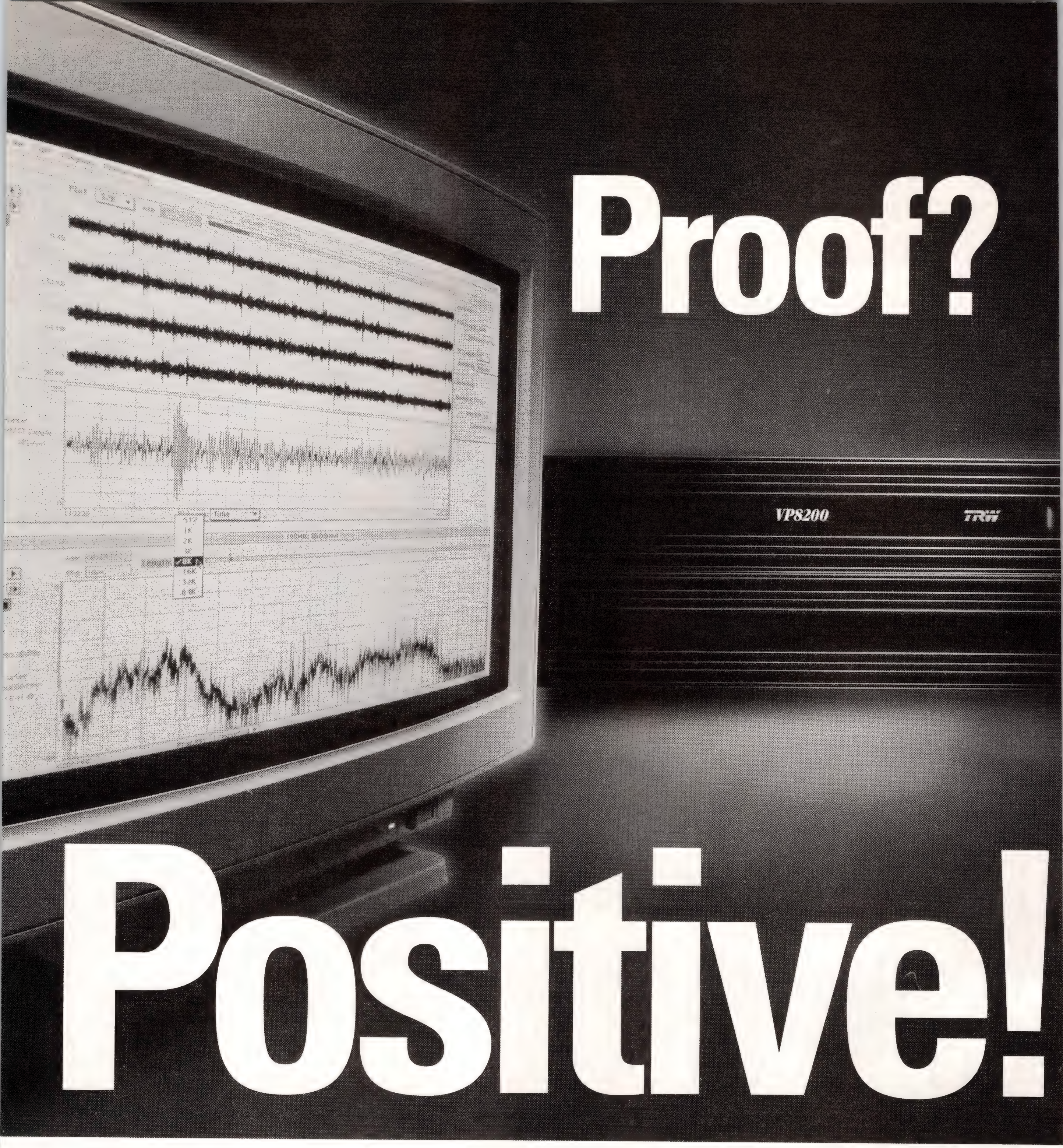
Whether you're making scientific measurements to 16-bit resolution, sampling data up to 330,000 points per second, or performing and plotting FFTs in real time, we have it all for ***under $1,000***. And, DT-Open Layers® software is the least expensive way to add quality to your Window's application: DT VEE,™ VB-EZ,™ and DataAcq SDK.™ Call us at ***800-525-8528*** for the perfect balance between performance and price.

DT-Open Layers
FOR MICROSOFT® WINDOWS™

DATA TRANSLATION®

World Headquarters: (508) 481-3700, UK Headquarters: (0734) 793838, Germany Headquarters: (07142) 95 31-0, Italy Headquarters: (030) 2425696.
Sales Offices: Argentina (1) 322-3791; Australia 2699-8300; Austria (222) 367660; Belgium (02) 466.81.99; Brazil 011-564-6024; Canada (800) 525-8528, (800) 268-0427; China (1)-8331145; Denmark 42 27 45 11; Finland (0) 3511800; France (1) 69.07.78.02; Greece (1) 361-4300; Hong Kong 515-0018; India 22-2831040; Israel 09-545685; Japan (03) 5379-1971, (03) 5489-3871, or (03) 5689-8000; Korea (2) 718-9521; Malaysia (3) 248-6786; Mexico 575-6091; Netherlands (70) 399-6360; New Zealand (9) 415-8362; Norway (22) 43 41 50; Portugal (1) 7934834; Singapore 773 4300; South Africa (12) 803-7680/93; Spain (1) 555-8112; Sweden 08-765 02 80; Switzerland (1) 908-1360; Taiwan (2) 3039836; Thailand (02) 281-9596; Turkey (212) 288-6213 6/22/94

CIRCLE NO. 28



Proof? Positive!

Why fret over development test? Think positive. Prove your results beyond the shadow of a doubt with the TRW VP8000 Wideband Signal and Test System.

The key is deep memory. The TRW VP8000 has up to 64 megabytes of it. With 500 Msample/sec capture and generation in both analog and digital. That's a 200MHz instantaneous bandwidth to soak up more real-world signal. In more detail. In less time. With less retesting. This assures that you catch problems in the lab. Not in production.

The TRW VP8000 proves to be a positive in other ways, too. A single workstation-based system, it replaces stacks of test and measurement devices. Integrating the accessibility of computers with the power of instrumentation. Delivering fast test set-up… a smooth upgrade path… portability… and affordability. So, don't just prove results the usual way – improve. Give us a call at

1-800-354-6195.

And let us prove how the TRW VP8000 will erase all your doubts about development test.

The TRW VP8000 – there's no doubt about it.

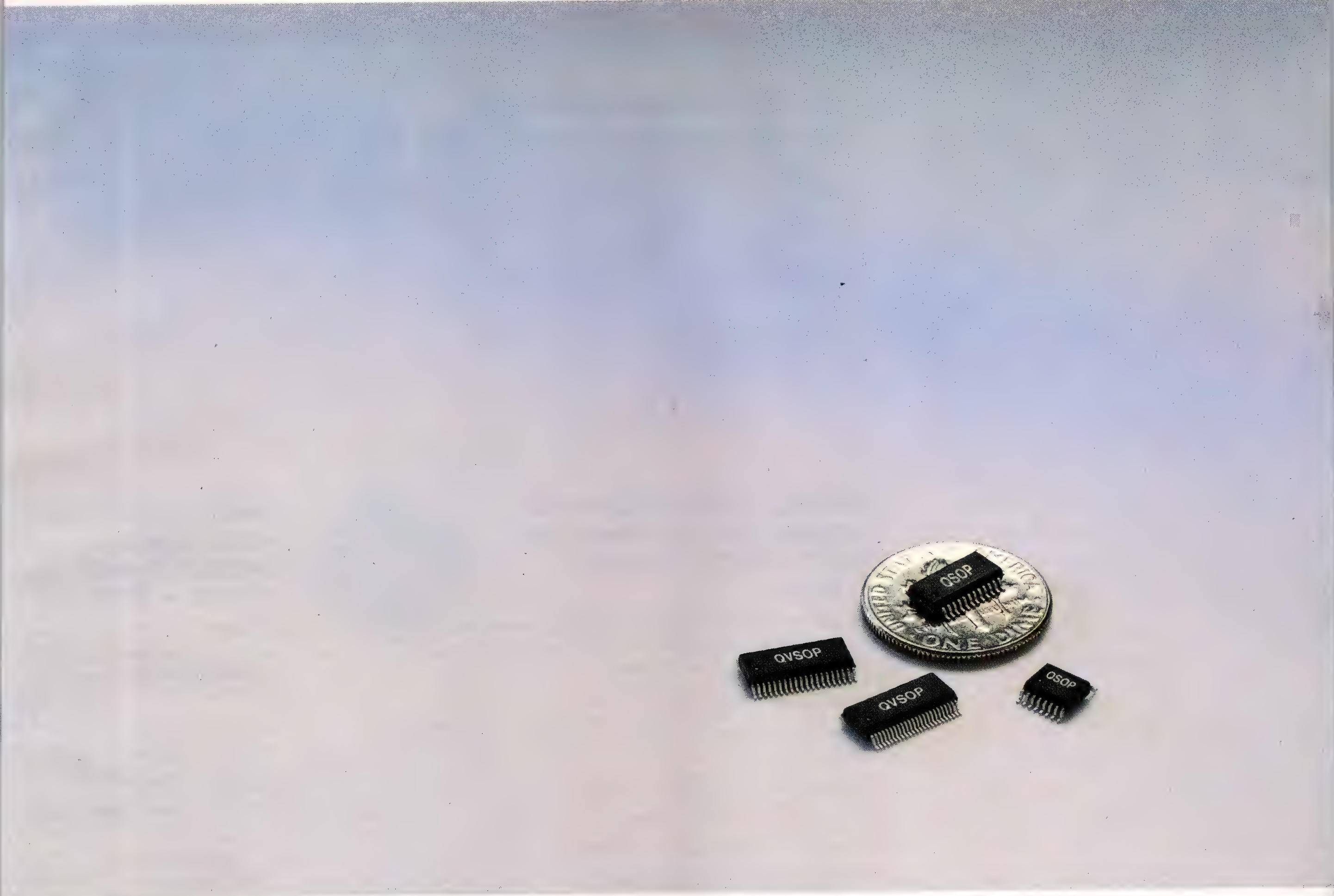
TRW

©TRW, Inc., 1994. TRW is the name and mark of TRW, Inc.

CIRCLE NO. 30

IT LOGIC CHIPS • QUICKSWITCH® PRODUCTS • FCT & 3.3V FCT LOGIC DEVICES

Minimal Marvels.



Of all the interface logic packages used in advanced surface mount manufacturing, QSOPs and QVSOPs give you the very tiniest footprint.

Up to 48 percent smaller than TSSOPs.

As the *QS* suggests, QSOPs are just a quarter the size of standard SOIC packages. QVSOPs, ideal for highest-density applications, are a mite smaller.

These minimal marvels deliver bigtime savings in board space. Which translates to a reduction in your overall system costs. You also get higher performance because of less ground bounce, shorter delays, and lower line and signal noise.

Excellent thermal characteristics include a high leadframe-to-plastic ratio that boosts reliability by more efficiently directing heat away from the die.

Availability is now. In any quantity. Nearly all major logic suppliers now second-source our industry-standard QSOP. And the QVSOP™ is a projected standard of the future.

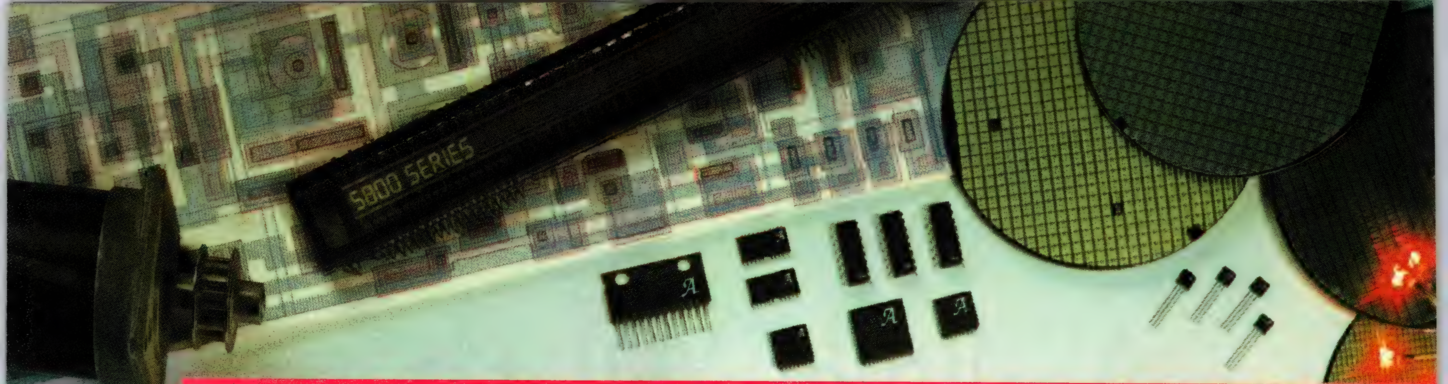
For application notes on our complete line of advanced packaging, call 800-609-3669. Or Fax 408-496-0773.

Good things come in small(er) packages.

Quality Semiconductor, Inc.

Q and QVSOP are trademarks of Quality Semiconductor, Inc.

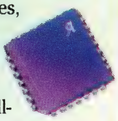
CIRCLE NO. 82



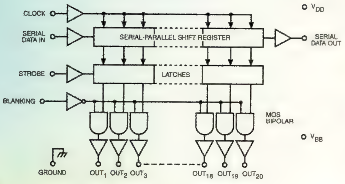
CURRENT SHOWCASE

BiMOS II 20-Bit Serial-Input, Latched Source Drivers with Active DMOS Pull-Downs — 5812-F

The 5812-F combines a 20-bit CMOS shift register, data latches, and control circuitry with high-voltage bipolar source drivers and active DMOS pull-downs for reduced supply current requirements.



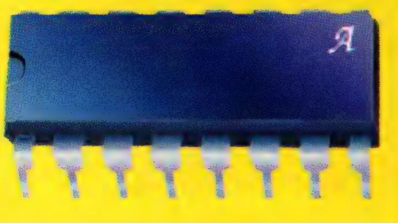
- High-Speed Source Drivers
- 60 V or 80 V Source Outputs
- Active DMOS Pull-Downs
- Low-Output Saturation Voltages
- 3.3 MHz Minimum Data Input Rate
- Reduced Supply Current Requirements

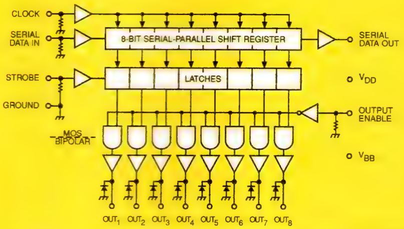


CIRCLE NO. 144

BiMOS II 8-Bit Serial Input, Latched Source Driver — 5895

The 5895 BiMOS II serial-input, latched source driver is designed for applications emphasizing low-output saturation voltages and currents to -250 mA per output.

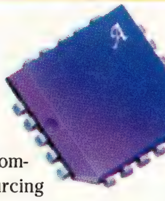



CLOCK
SERIAL DATA IN
STROBE
GROUND
8-BIT SERIAL-PARALLEL SHIFT REGISTER
LATCHES
SERIAL DATA OUT
V_{DD}
OUTPUT ENABLE
MOS
BIPOLAR
V_{BB}
OUT_1 OUT_2 OUT_3 OUT_4 OUT_5 OUT_6 OUT_7 OUT_8

- Low Output-Saturation Voltage
- Source Outputs to 50 V
- Output Current to -250 mA
- 3.3 MHz Minimum Data-Input Rate
- Low-Power CMOS Logic & Latches

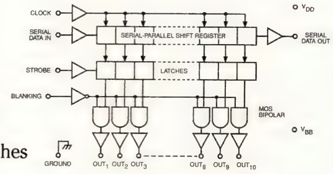
CIRCLE NO. 145

BiMOS II 10-Bit Serial-Input, Latched Source Drivers with Active DMOS Pull-Down — 5810-F



The 5810 combines 10-bit CMOS shift register and accompanying data latches, control circuitry, bipolar sourcing outputs with DMOS active pull-downs.

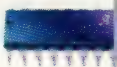
- High-Speed Source Drivers
- 60 V or 80 V Minimum Output Breakdown
- Active DMOS Pull-Downs
- Low Output Saturation Voltages
- Low-Power CMOS Logic and Latches
- 3.3 MHz Minimum Data Input Rate



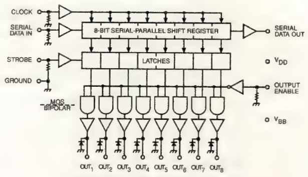
CIRCLE NO. 146

BiMOS II 8-Bit Serial-Input, Latched Source Drivers — 5890

Frequently applied in non-impact printer systems, the 5890 is a BiMOS II serial-input, latched source (high-side) driver.



- 50 V or 80 V Source Outputs
- Output Current to -500 mA
- Output Transient-Suppression Diodes
- 3.3 MHz Minimum Data-Input Rate
- Low-Power CMOS Logic and Latches


CLOCK
SERIAL DATA IN
STROBE
GROUND
8-BIT SERIAL-PARALLEL SHIFT REGISTER
LATCHES
SERIAL DATA OUT
V_{DD}
OUTPUT ENABLE
MOS
BIPOLAR
V_{BB}
OUT_1 OUT_2 OUT_3 OUT_4 OUT_5 OUT_6 OUT_7 OUT_8

CIRCLE NO. 147

Take A Test Drive... Call For Samples

Try these Allegro ICs in your breadboard. You'll find that you'll reduce your component count, increase reliability through use of monolithic solutions and protection features, as well as potentially lowering overall manufacturing costs. Sample and detailed technical information are now available. Just give us a call.

THE PACE QUICKENS

Allegro™
MicroSystems, Inc.

FORMERLY SPRAGUE SEMICONDUCTOR GROUP

CALL 1 • 508 • ALLEGRO

115 Northeast Cutoff, Worcester, Massachusetts 01615

Compression techniques conserve electromagnetic-spectrum space

The overcrowded electromagnetic spectrum is continuously striving to meet ever-increasing demands. Digital enhancements to the cellular-phone infrastructure are helping to preserve some of this precious commodity.

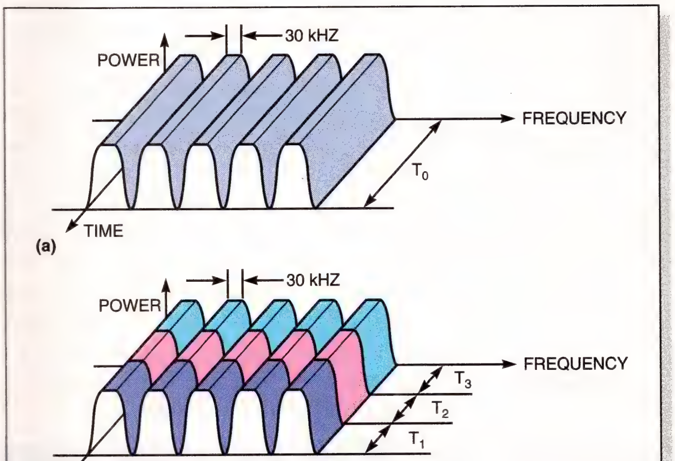
JOHN GALLANT, TECHNICAL EDITOR

The cellular-phone industry is facing a double-edged problem: On the one hand, its customer base is expanding; on the other, the amount of electromagnetic space allocated to cellular service is fixed. To neutralize the increase in demand, cellular-carrier companies are implementing a host of digital data-compression techniques to conserve spectrum capacity. The industry is experimenting with three digital compression techniques: time-division multiple access (TDMA), code-division multiple access (CDMA), and cellular digital packet data (CDPD).

The current analog Advanced Mobile Phone System (AMPS) uses a 25-MHz band of the spectrum—from 824 to 849 MHz—to transmit and another 25-MHz band—from 869 to 894 MHz—to receive. AMPS divides the available 25-MHz spectrum into 30-kHz-wide channels for FM communications. This method of dividing the spectrum into multiple channels is frequency-division multiple access (FDMA).

Dividing the 25-MHz FDMA spectrum into 30-kHz frequency bins produces 832 available channels for FM transmission. In practice, a single carrier company cannot use all of the frequencies because the FCC allots one-half of the channels to each of two competing carrier companies operating in each city. The allotment yields 416 channels per carrier. The carriers use 17 channels for timing and control, which yields 399 channels for voice transmission.

In addition, the analog system requires that the desired signal must be 18 dB above any noise and interference on the same channel to provide acceptable call quality. To provide this attenuation, any one cell can use only one-seventh of the cellular frequencies allotted to a carrier. Adjacent cells cannot use the same frequencies. The frequency allocation allows two cells on the same frequency to be far enough apart to avoid mutual interference. Therefore, dividing the 399 channels by seven yields 57



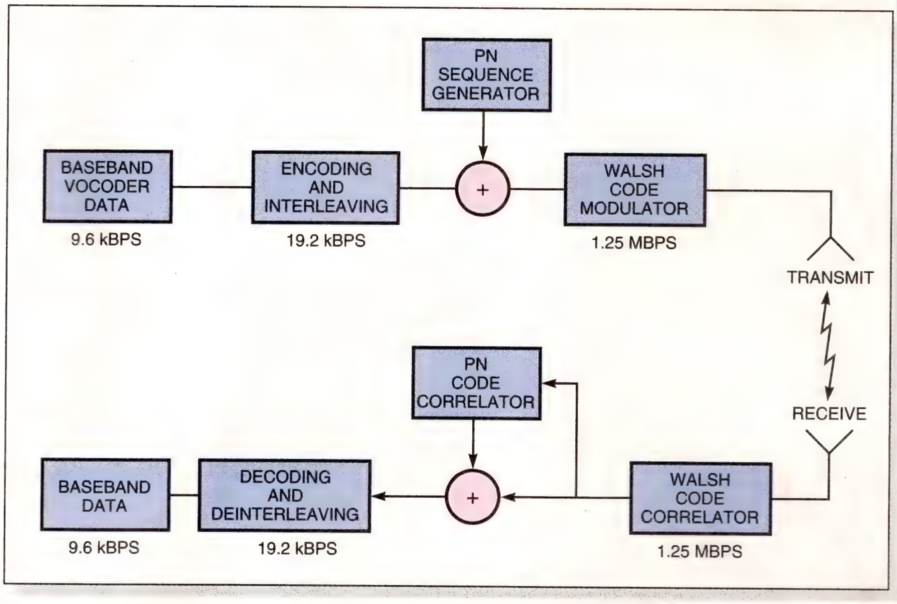
The FDMA analog AMPS frequency spectrum is divided into 30-kHz-wide bins for voice and data transmission (a). TDMA occupies the same frequency spectrum as FDMA but digitally compresses voice into three time slots (b). CDMA's 1.25-MHz spectrum approximates white noise where a pseudorandom sequence determines individual channels (c).

available voice-transmission frequencies per cell.

TDMA uses the same 30-kHz channels and has the same spectrum restrictions as those of FDMA but adds time-sharing of three users on each channel. The Telecommunications Industry Association (TIA) has adopted TDMA as a standard, called IS-54. IS-54 provides dual modes for transmitting analog and digital data. The digital mode samples voice signals at a vocoder rate of 8 kbps.

In addition, the digital mode for TDMA employs a baseband data-compression algorithm called vector-sum excited linear-predictive (VSELP). VSELP compresses 20 msec of data into 6.6 msec, which allows three TDMA slots for every transmission. Therefore, TDMA promises a threefold increase in capacity over the 57 analog AMPS channels without occupying additional bandwidth in the electromagnetic spectrum.

The TIA has also adopted CDMA as a standard, called IS-95. CDMA is a more complicated specification than is TDMA but potentially offers 10 to 20 times the capacity of the current AMPS. Qualcom Inc (San Diego) developed CDMA, a spread-spectrum technique. A CDMA vocoder encodes voice at 8 kbps, which produces a baseband 9600-bps data-transmission rate. By measuring the voice activity, the vocoder can lower the bit rate to 1 kbps during periods of no voice activity. CDMA transmits additional bits to permit interleaving and forward error correction, so the transmitted symbol rate can be as high as 19.2 kbps.



A simplified block diagram of a CDMA channel shows 9.6-kbps baseband data being encoded and interleaved before a pseudorandom sequence and a Walsh code modulator perform spread-spectrum modulation. The transmitted spectrum is 1.25 MHz wide.

A conventional digital phone would use the symbol rate to modulate an RF carrier using frequency-shift-keying (FSK) or phase-shift-keying (PSK) modulation. Instead, the symbol stream in CDMA combines in a digital adder with a stream of 0.8-μsec pseudorandom-noise (PN) pulses, called chips. The chips spread the original 19.2-kbps symbol bandwidth to occupy approximately 1.25 MHz of bandwidth (the reciprocal of 0.8-μsec pulses). CDMA transmits the chips using quadrature PSK (QPSK).

To decode the chip stream at the receiver, the known PN code combines with the received chip stream in another digital adder, and the original symbol stream emerges. In CDMA, multiple users share a single wideband carrier frequency, but each user uses a different PN code. Because the PN code defines the channel, there are no restrictions on adjacent cells broadcasting at the same frequency. CDMA uses two carrier frequencies separated by 45 MHz to provide forward and reverse between a mobile unit and a base station.

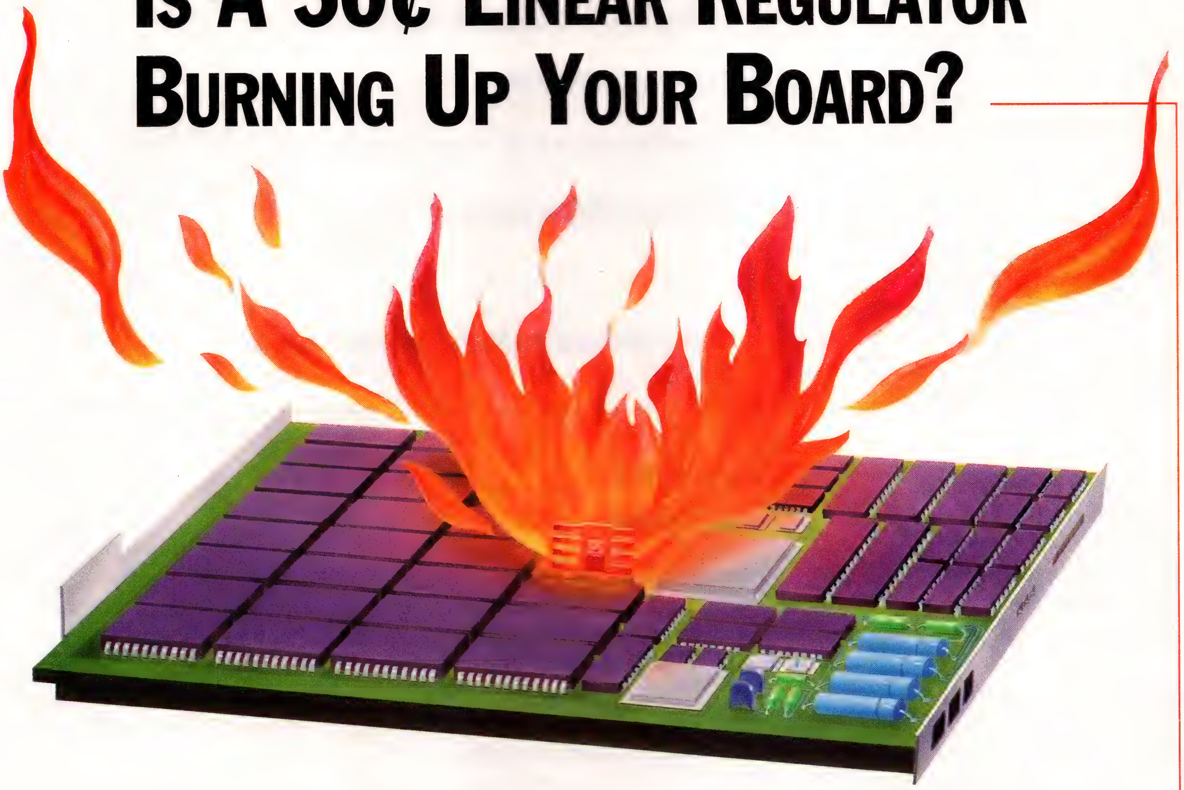
Using an appropriate PN code, the resulting spectrum of the modulation has a uniform distribution over the 1.25-MHz bandwidth. The spectrum approximates the spectrum of white noise. A problem occurs when too many subscribers use the same 1.25-MHz channel because their signals raise the noise floor, and they unintention-

LOOKING AHEAD

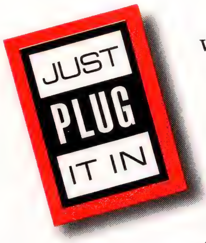
Most cellular-carrier companies plan to employ cellular digital packet data (CDPD) on their Advanced Mobile Phone System (AMPS) network to provide digital packet-data delivery. However, the jury is still out on the deployment of time-division multiple access (TDMA) and code-division multiple access (CDMA) on unused AMPS channels. Most carriers will most likely implement TDMA instead of CDMA on these channels in the immediate future. TDMA's advantage over CDMA is simplicity. Some proponents of TDMA don't believe that CDMA will work and, like the man from Missouri, are waiting to be shown. Because TDMA occupies the same 30-kHz channels as AMPS, TDDA deployment can be granular and doesn't require the large piece of spectrum (greater than 1.25 MHz) that a single CDMA channel requires.

CDMA has a handful of proponents, however, including GTE Mobile Communications, Pactel, and US West. These carriers are performing tests in US cities to prove the CDMA concept. If the tests go well, you may see some CDMA deployment next year. But how can users avail themselves of these cellular digital enhancements? It means that modem vendors will have to offer dual-mode modems that offer TDMA or CDMA operation with a fallback mode to AMPS with CDPD capability. With dual-use modems, if users roam into an area lacking TDMA or CDMA coverage, the modem falls back to AMPS so that users can still use CDPD to transmit digital packet data.

IS A 50¢ LINEAR REGULATOR BURNING UP YOUR BOARD?



PLAY IT COOL WITH OUR LOW COST 1 AMP INTEGRATED SWITCHING REGULATOR



Do you have a board with a 3-terminal linear regulator that's generating more heat than an irate customer? Are you locked into a tight compact design that leaves no extra space for a larger heatsink? Fortunately, you can now play it cool with an innovative product from Power Trends – a 1-Amp Integrated Switching Regulator (ISR). Power Trends' 1-Amp ISRs are pin-compatible with existing 3-terminal "78 and 79 Series" linear regulators, fit into the same space, and are just as easy to use. With 85% efficiency, our ISRs provide a cool replacement alternative for hot linear regulators. Of course they cost more, but they could save you thousands. Specifications include: laser-trimmed output voltages from 3.3 to 12 Volts, calculated MTBF of over 1,000,000 hours, 0.5% line and load regulation, and power densities of 25 to 100 watts per cubic inch. So if you have a heat/space/reliability problem now, or just want to make sure you don't have one in the future – check out Power Trends' super efficient ISRs. *Call or write for more information, and ask about samples!* ***1-800-531-5782.***

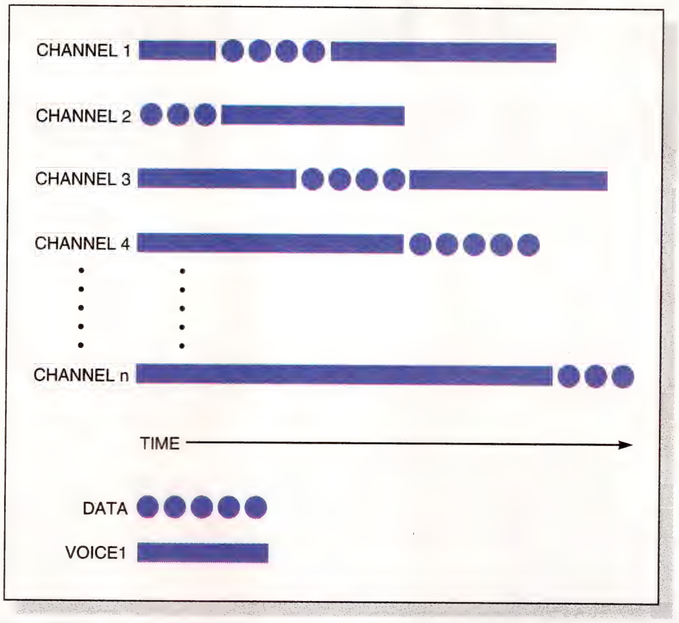
POWER TRENDS®

1101 North Raddant Road, Batavia, IL 60510 • (708) 406-0900 • Fax (708) 406-0901

CIRCLE NO. 81

ally jam each other. To overcome this problem, a 64-bit Walsh code modulates the chip stream again at the transmitter. The code generates 64 orthogonal channels in the 1.25-MHz bandwidth that ignore each other.

Theoretically, if the entire cellular bandwidth were allocated to CDMA, a single transmitter could support as many as 1200 calls. This assumes that the entire cell uses only one pilot channel, one synchronization channel, and one paging channel. CDMA requires these extra channels for control and timing of the CDMA system. In contrast, the current AMPS FDMA system can support only 57 calls on a transmitter.



In CDPD, digital data packets and voice segments share the same frequency. When a voice signal ramps up on the channel in use, the digital data channel hops over to an idle channel.

Finding empty spaces

The CDPD network is another means by which cellular carriers are adding capacity to AMPS (**Ref 1**). CDPD attempts to exploit the existing capabilities of the AMPS cellular infrastructure. For example, the cellular phones involve extended moments during which the channel is idle. CDPD detects these moments, packages digital data in small packets, and sends the data during the idle time. If a voice signal ramps up on the channel while data are transmitting, a "sniffer" searches for another idle channel to redirect the packet data to an unused channel—a technique called "channel hopping." Therefore, CDPD enhances the efficiency of the cellular channel but doesn't impact voice communications on the channels or require additional electromagnetic space.

By adding a small amount of CDPD equipment to cellular sites, carriers can provide both digitized voice and data to the analog cellular-phone infrastructure. Users can communicate via data, fax, and voice from a CDPD-compatible modem.

But how do the cellular carriers plan to handle all of these digital enhancements to the AMPS network? According to Russ Brankley, general manager for product management for wireless data at Bell Atlantic, channel allocation is the preferred method of implementation. Bell Atlantic offers TDMA communication in some markets and sees CDMA as a future medium. The company also dedicates some of its FDMA channels to TDMA communications. In addition, Bell intends to reserve a single channel for CDPD operation. The company will dedicate the CDPD channel to digital data without analog voice or channel-hopping.

Chuck Parish, general manager for wireless data at GTE Mobile Communications, feels that the conversion of the cellular spectrum to TDMA or CDMA will occur in two stages. GTE wants to deploy CDMA and CDPD on the cellular network but expects that the transition from AMPS to CDMA will go slowly. In the near term, GTE plans to conduct trials of voice communications using CDMA. These trials will take place in Austin during the fourth quarter of this year. If the trials go well, a commercial roll-out of CDMA for voice only will happen next year.

The CDMA channel will initially occupy approximately 10% of the existing 25-MHz AMPS spectrum. However, because CDPD delivers 10 to 20 times the capacity of AMPS, the aggregate capacity should be as good as or better than AMPS. GTE is planning to deploy CDPD on the remaining 30-kHz bandwidth AMPS channels using channel hopping.

In the long term, which may be four or five years, CDMA will transmit digital data as well as voice. By then, the CDPD Forum, a trade association working toward interoperability among service carriers and user equipment, should have developed a new air-link protocol to transmit data over a circuit-switched connection.

McCaw Cellular is implementing TDMA and CDPD in its markets. Dave Brandos, director of product development in the wireless data division at McCaw, says that TDMA provides a more granular strategy for allocating spectrum space than CDMA does. TDMA occupies the same channel width as FDMA, so that a few 30-kHz TDMA channels can work without requiring the 1.25-MHz chunk of spectrum that CDMA does. McCaw plans to implement CDPD on the remaining AMPS channels.

Brandos says that you can't implement CDPD on a TDMA channel because no packet service capability uses TDMA. However, with a mix and match of TDMA and AMPS channels, McCaw can provide complete digital service because CDPD is encoded on all McCaw's AMPS channels. EDN

References

1. Gallant, John, "The CDPD network," *EDN*, Oct 13, 1994, pg 40.
2. Whipple, David, "The CDMA Standard," *Applied Microwave & Wireless*, Winter 1993, pg 24.
3. Kerr, Richard, "CDMA Digital Cellular," *Applied Microwave & Wireless*, Fall 1993, pg 30.

You can reach Technical Editor John Gallant at (617) 559-4666, fax (617) 558-4470.

VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

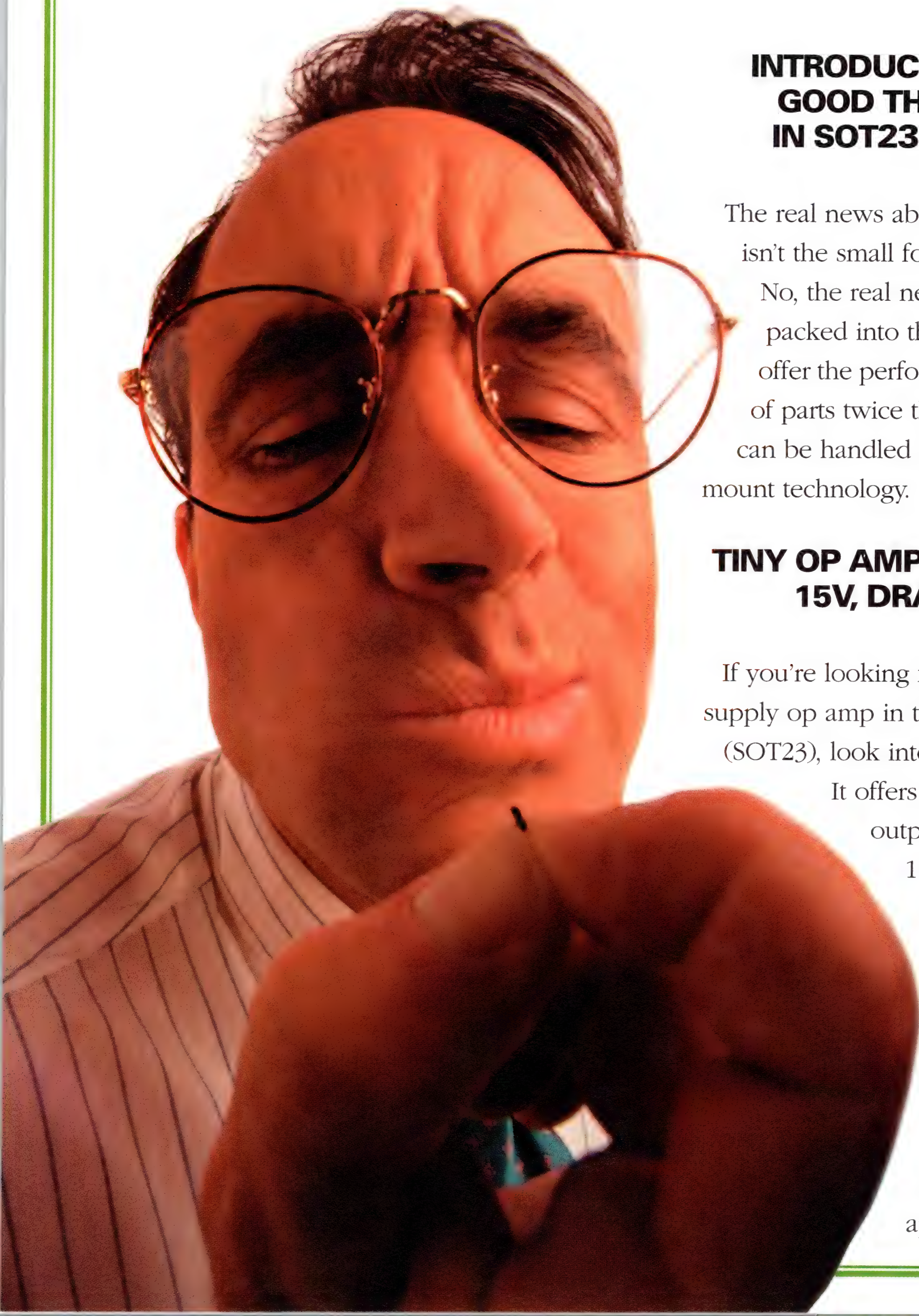
High Interest	Medium Interest	Low Interest
595	596	597

making waves

To take advantage of the latest wave of analog innovations, follow these simple instructions.

National Semiconductor™

1. Squint.



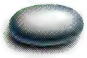
INTRODUCING TINYPAK. GOOD THINGS COME IN SOT23 PACKAGES.

The real news about National TinyPak™ isn't the small footprint SOT23 package. No, the real news is the power we've packed into them. Our Tiny devices offer the performance and functionality of parts twice their size. And TinyPak can be handled by standard surface mount technology.

TINY OP AMP RUNS ON 3V TO 15V, DRAWS 0.5mA.

If you're looking for the best single supply op amp in the smallest package (SOT23), look into the TinyPak LMC7101. It offers rail-to-rail input and output, operates on 3V to 15V and draws a low 0.5mA of current. This unbeatable combination of size and performance makes the LMC7101 the perfect choice for a wide variety of portable and handheld applications. And at $0.84

Black Ant


Hummingbird Egg

Cuban Frog

SOIC

SOT23-5

How small is our TinyPak? So small it makes ants look as big as aardvarks and SO8s look, well, a whole lot bigger than they used to look.

(1000 unit), even the price is tiny. (Also available in plastic DIP package.)

TINY TEMP SENSORS OFFER +10mV/˚C SENSITIVITY FROM -20˚C TO +100˚C.

Think of the LM45 temperature sensor as a Tiny alternative to thermistors. The LM45 operates on 4V to 10V power supplies. Its specified temperature range is -20˚C to +100˚C with output scale factor of +10mV/˚C, a guaranteed accuracy of +/-2˚C at 25˚C and low power of 120µA maximum. It's designed for single power supplies and requires no external calibration signal conditioning or linearization. Although the LM45 is Tiny, it's destined to play a large role in applications from battery and microprocessor power management to process and HVAC control. LM45 prices start at $0.90 (250 unit).

TINYPAK VOLTAGE REFERENCES WITH PRECISION OUTPUT FROM 1.2V TO 10V.

Here are two more Tiny wonders. The LM4040 and LM4041 precision voltage references offer fixed output of 1.2V, 2.5V, 4.096V, 5V, 8.192V, 10V or adjustable output from 1.24V to 10V. Both offer +/-0.1% to +/-2.0% output tolerance. Neither requires an external output capacitor. And with pricing starting at $0.92 (100 unit), these TinyPak (SOT23) references are becoming very big hits.

OUR LOW DROPOUT REGULATOR IS TINY. SO IS ITS 120mV DROPOUT VOLTAGE.

The LP2980 minimizes board space and maximizes battery life. It offers fixed outputs of 3.0V, 3.3V and 5.0V, a dropout voltage of 120mV at 50mA and a quiescent current of 375µA at 50mA. You can select output precision of +/-0.5 or +/-1.0%. And in shutdown mode, the quiescent current is less than 1µA. This big performance combined with its small size and price—$0.77 (1000 unit)—make the LP2980 perfect for battery-powered applications from cellular phones to notebook computers.

2. Open your ears.

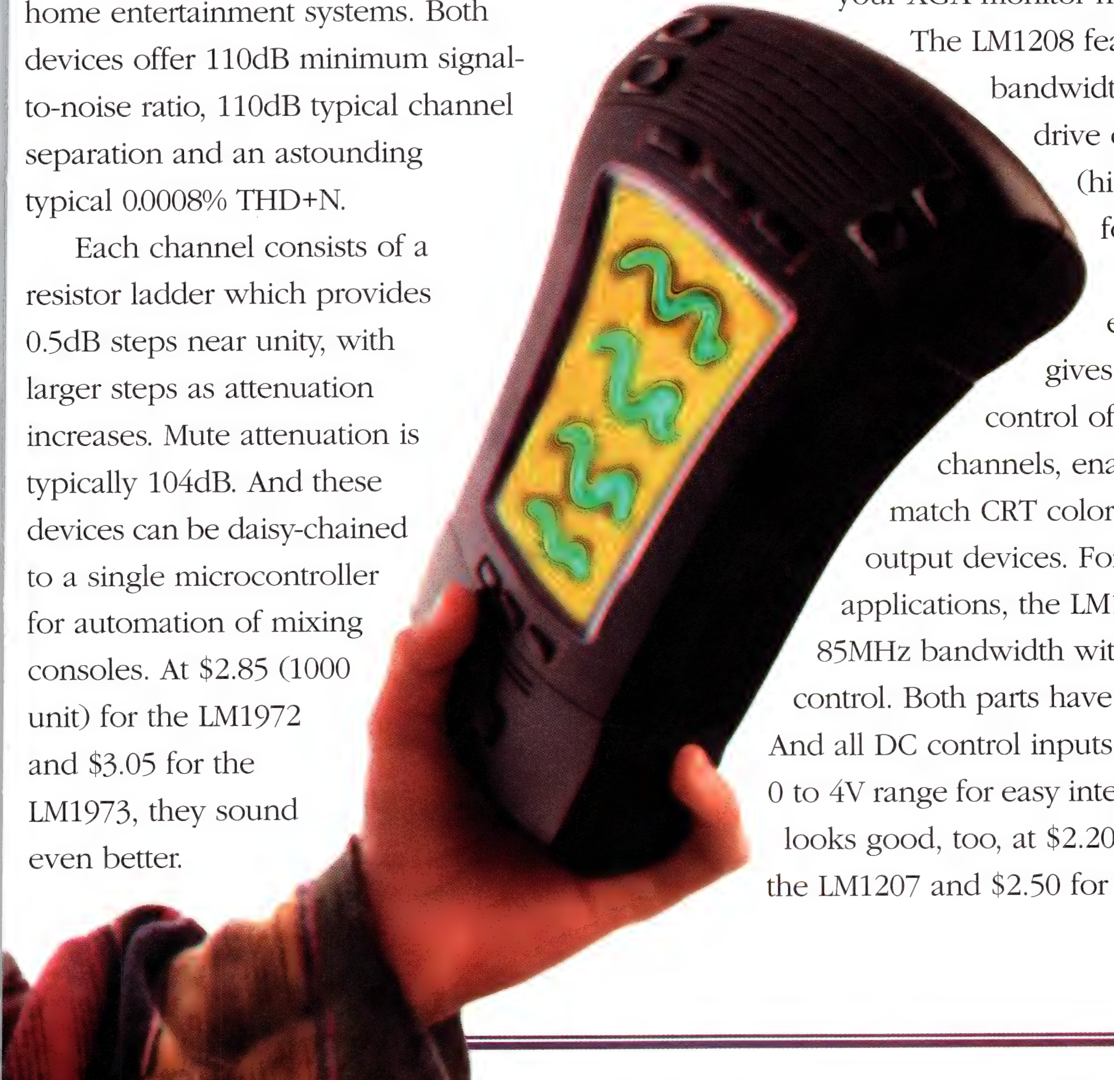
MEET BOOMER.
1W AUDIO FROM 5V.

Want your innovation loud and clear? Listen to National Boomer® (LM4860 and LM4861). The LM4860 delivers a thundering 1W of output power (1/2W for the LM4861) into an 8Ω load, with less than 1% THD+N from a 5V supply. It requires no external capacitors or snubber circuits. And in shutdown mode it typically draws less than 1µA. All of which makes Boomer the sound solution for everything from PCs to games to cellular phones. And the LM4860 price is a very quiet $1.99 (1000 unit), $1.89 for the LM4861.

OVERTURE AUDIO µPOTS SING. "CLICKLESS" LEVEL CONTROL.

Speaking of sound solutions, National Overture™ µPot audio attenuators, LM1972 (2-channel) and LM1973 (3-channel) bring clearer, purer sound to high-end audio applications, from studio equipment to home entertainment systems. Both devices offer 110dB minimum signal-to-noise ratio, 110dB typical channel separation and an astounding typical 0.0008% THD+N.

Each channel consists of a resistor ladder which provides 0.5dB steps near unity, with larger steps as attenuation increases. Mute attenuation is typically 104dB. And these devices can be daisy-chained to a single microcontroller for automation of mixing consoles. At $2.85 (1000 unit) for the LM1972 and $3.05 for the LM1973, they sound even better.



OPEN YOUR EYES, TOO. MATCHED COLOR FROM OUR XGA VIDEO PREAMPS.

LM1208 video preamp gives you greater control over each color channel, and gives users the ability to perfectly match video color to output color.

Here are a pair of video preamps designed to cover your XGA monitor needs.

The LM1208 features 130MHz bandwidth with 40dB drive control range (highest available) for high-end applications. The extended range gives greater dynamic control of individual color channels, enabling users to match CRT color to that of other output devices. For low-end XGA applications, the LM1207 offers an 85MHz bandwidth with 6dB of drive control. Both parts have on-chip blanking. And all DC control inputs operate over 0 to 4V range for easy interface. The price looks good, too, at $2.20 (1000 unit) for the LM1207 and $2.50 for the LM1208.

3. Catch.

AT 192kS/s, IT'S THE WORLD'S FASTEST 16-BIT ΔΣ ADC.

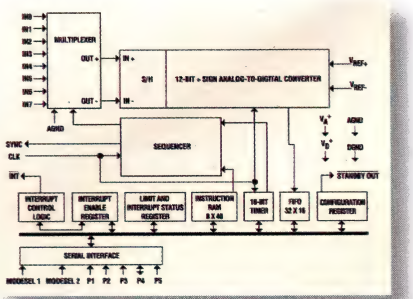
If you have a fast dynamic signal to catch, catch these specs first. The ADC16071 and ADC16471 offer 16-bit resolution, 192kS/s (thousands of samples per second) throughput, 64x oversampling, a low 0.003%THD at 1kHz, a high SINAD

With 192kS/s throughput and 64x oversampling, our ADC16071/471 will keep even the fastest DSP chip busy.

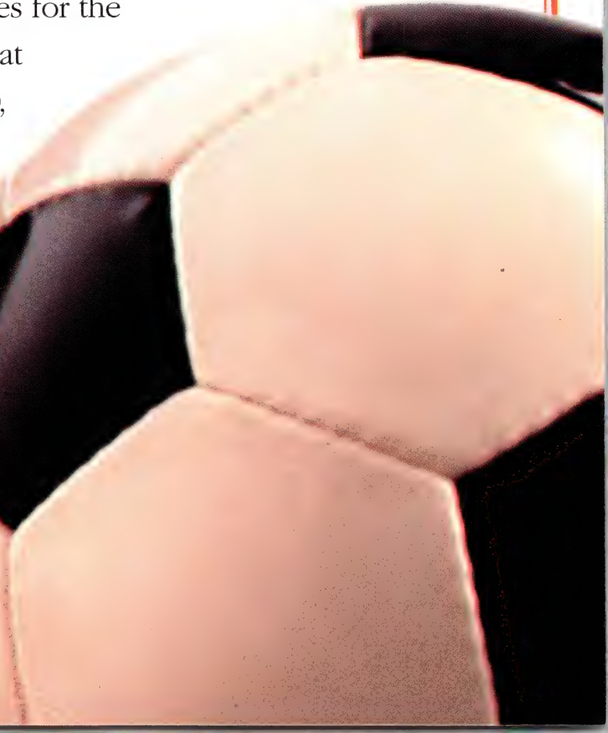
80dB min at 48kS/s, a great speed/power tio of 275mW at 48kS/s and shutdown pability, all from a 5V supply. And the DC16471 has an on-chip reference. unds like the perfect performance for a t of high-end applications like, say, DSP ont-ends, acoustic and vibration analysis, lephony, voice recognition and audio. At 7.80 for the ADC16071 (100 unit) and 8.50 for the ADC16471, they’re going fast.

AND AT 140kS/s, WE’VE GOT THE WORLD’S FASTEST SERIAL I/O DAS, TOO.

The new 12-bit LM12434 and LM12438 erial I/O data acquisition systems are creamers. The LM12434/8 delivers 140kS/s roughput while consuming only 40mW om a 5V supply, while the LM12L438 hits 05kS/s consuming 20mW from 3.3V. Both evices are true systems-on-a-chip. They eature a user-programmable sequencer, equire zero glue logic and connect directly to National Microwire™/PLUS, SPI/QSPI, TMS320, I^2C, 8051 and SCI interfaces, so they’re quick and easy to design with. And speaking of easy, we offer National WaveVision,™ our powerful Windows®-based design evaluation software, free to get you started. Prices for the LM12434/8 start at $18.20 (100 unit), $17.60 for the LM12L438.



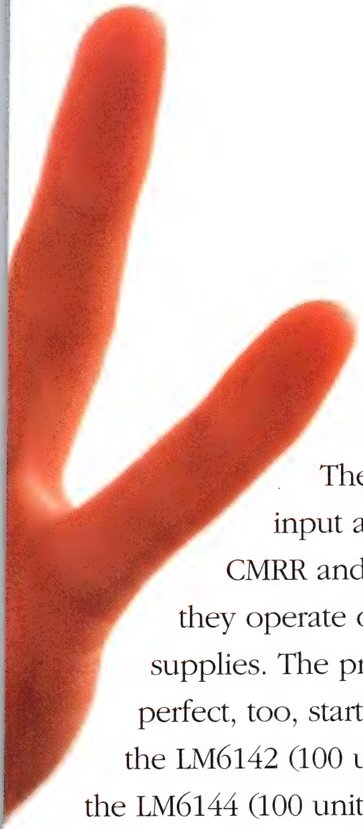
Our new LM12438 contains everything you need to build a complete data acquisition system—all on a single chip.



4. Do more. Eat less.

OP AMPS DO 17MHz GBW. EAT ONLY 650μA.

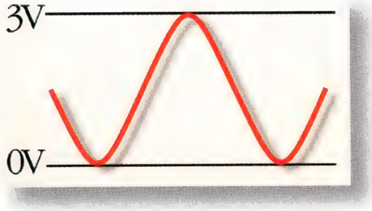
Introducing the world's most perfect single supply op amps. Namely, the LM6142 (dual) and LM6144 (quad). Both devices deliver an astounding 17MHz gain-bandwidth at 50kHz (enough to replace several of your not so perfect op amps) while drawing just 650μA/amplifier



of supply current. They offer rail-to-rail input and output, 107dB CMRR and PSRR=87dB, and they operate on 1.8V to 24V supplies. The prices are nearly perfect, too, starting at $2.34 for the LM6142 (100 unit) and $3.62 for the LM6144 (100 unit).

TINY VIDEO OP AMPS BRING BIG PERFORMANCE TO SINGLE SUPPLY SYSTEMS.

The LM7131 may come in a TinyPak (SOT23-5), but its performance is huge. Designed to bring high performance video to battery-powered and desktop systems, the LM7131 specs are guaranteed at 3V, 5V and +/-5V. With a 70MHz gain-bandwidth at 5V, it delivers solid video performance. And with typical supply currents of 7.0mA at 5V and 6.5mA at 3V, it's easy on batteries. The LM7131 is ideal for everything from driving flash A/D converters and back-terminated video cables to portable and desktop computer video output, desktop teleconferencing, multimedia boards and even digital audio. The LM7131 is available in SO8 and DIP packages as well as the TinyPak. And the price starts at a tiny $1.00 (100 unit).



The LM6142/44 and LMC6462/64 low power op amps deliver rail-to-rail performance.

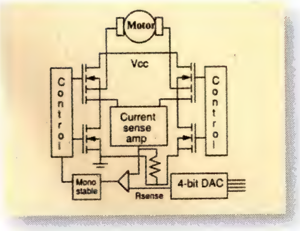
THE WORLD'S LOWEST POWER, HIGH PERFORMANCE 3V TO 15V RAIL-TO-RAIL I/O OP AMPS.

With their incredibly low supply current of 20µA per channel, the LMC6462 (dual) and LMC6464 (quad) set the low power standard for 3V to 15V op amps. Both devices deliver rail-to-rail input and output, an ultra low input current of 10pA max, high voltage gain of 128dB and low offset voltage of 0.5mV max. All of which makes them perfect for battery-powered applications, including cellular phones, notebook computers, PDAs and portable instruments. All at prices from $2.10 (100 unit) for the LMC6462 and $2.50 (100 unit) for the LMC6464.

5. Squeeze here.

3A MOTOR DRIVER WITH BUILT-IN PWM DOES MORE IN LESS SPACE.

The LMD18245 is a fully integrated 3A H-Bridge motor driver that greatly simplifies system design by including everything you need on chip. What it includes is pulse width modulation (PWM) in the form of fixed off-time pulse control, a 4-bit DAC for easy motor stepping and current control, and device protection through thermal shutdown, current limit and undervoltage lockout. It features a low Rdson of .3Ω per switch and its LMDMOS advanced IC process delivers



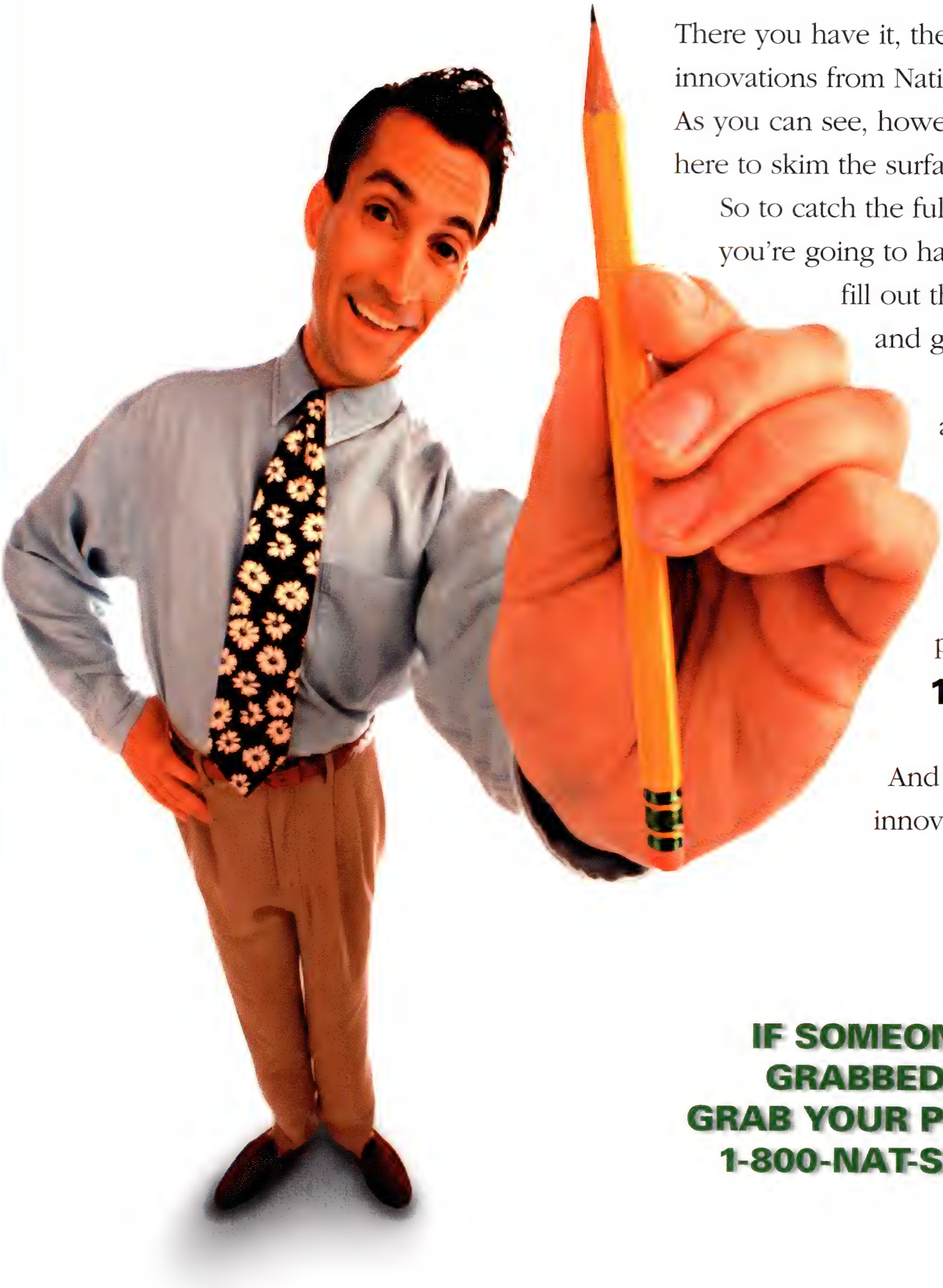
The LMD18245 motor driver includes everything you need to get your motor running.

the maximum integration of power, protection and control. LMD18245 prices start at $9.95 (100 unit).

PRECISION SECONDARY REGULATOR/DRIVER TRIMMED TO 3.3V AND 5V. AND IT'S TINY, TOO.

Now there's a smaller, easier way to control output in regulated power supplies. The LM3411 secondary/regulator driver is a fully integrated reference, op amp and opto-driver. It's trimmed to 0.5% initial tolerance at 3.3V and 5V so it requires no external pots or precision resistors. All that integration is in a SOT23 TinyPak. And prices start at $0.89 (100 unit).

6. Grab your pencil.



There you have it, the latest wave of analog innovations from National Semiconductor. As you can see, however, we only had room here to skim the surface.

So to catch the full power of the wave, you're going to have to grab your pencil, fill out the attached reply card, and get your hands on product sample kits and information kits.

Or, if you've seen something here you can't live without for a few days, grab your phone instead and dial **1-800-NAT-SEMI, EXT. 329.** And we'll rush our latest innovations your way.

IF SOMEONE ALREADY GRABBED THE CARD, GRAB YOUR PHONE INSTEAD. 1-800-NAT-SEMI, EXT. 329.

TinyPak,Overture, MicroWire, WaveVision and the National worldmark are trademarks of National Semiconductor Corporation. The Boomer registered trademark is licensed to National Semiconductor for audio integrated circuits by Rockford Corporation. Windows is a registered trademark of Microsoft Corporation. ©1994, National Semiconductor Corporation. All rights reserved.

The Winning Hand

IDT's QSOP...*Your Ace In The Hole!*

IDT adds the Quarter-Size Outline Package (QSOP) to complete its winning hand of surface-mount packages for its high-speed FCT Logic family. With products available in TSSOP, QSOP, SSOP, and standard SOIC packages, IDT now offers the industry's widest line of high-density packaging for both Octal and Double-Density logic.

Dramatic Space Savings!

At half the length and width of industry standard SOIC packages, the new QSOP package is the most compact Octal package available. In addition to the area savings, the new package is only 0.0645 inches high, making it ideal for low profile applications.

The Fastest 5V and 3.3V Logic

IDT's Logic family is the highest performing, lowest power bus interface solution. Available in a wide variety of 5V and 3.3V functions, and speed grades from 6.5ns to 3.2ns (t_{pd} max), IDT's FCT Logic family supports all levels of performance at competitive prices.

Quiet, Low-noise Outputs

IDT's FCT Logic is offered in a variety of low-noise output drive configurations to minimize ground bounce and to match specific design requirements. Output configurations include: standard TTL-compatible high drive and very low-noise balanced drive with source terminating resistors.

Compact IDT FCT Logic Packaging

Package	Ordering Code	Pin-Pitch (mm)	Area (mm²)	Length (mm)	Width (mm)	Height (mm)
QSOP 20-pin	Q	0.635	52.1	8.7	3.9	1.6
SSOP 20-pin	PY	0.650	56.0	7.2	5.3	1.9
SOIC 20-pin	SO	1.270	133.1	12.8	7.5	2.5
TSSOP 48-pin	PA	0.500	102.1	12.6	6.2	1.1
SSOP 48-pin	PV	0.635	164.4	15.9	7.5	2.6

Calculate the Savings

Call or FAX us today and receive a free IDT calculator, QSOP cross reference guide, sample package card, Logic Design Guide and Logic Data Book.

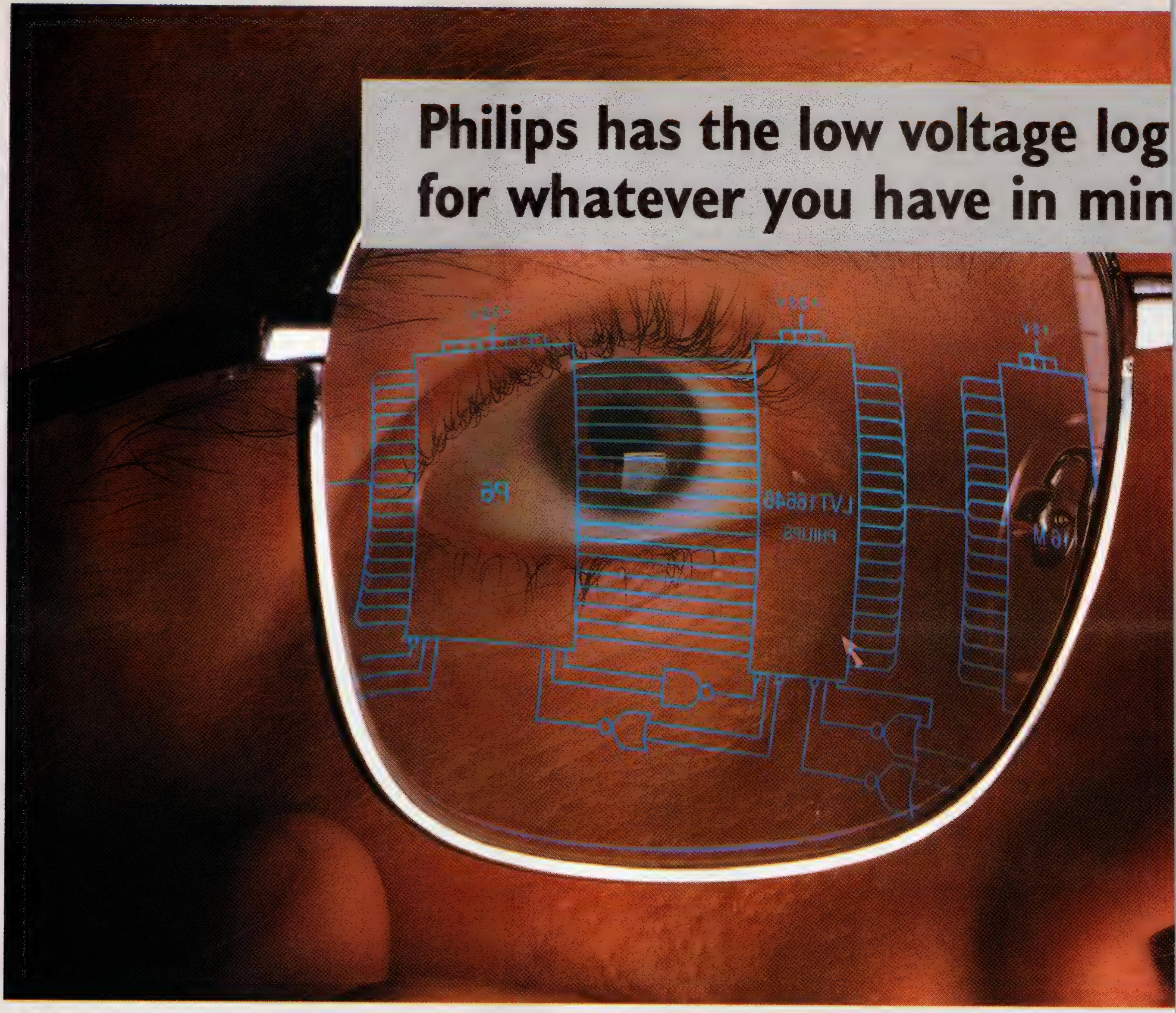
Actual Size

(800) 345-7015 • FAX: 408-492-8674

ASK FOR KIT CODE 3151

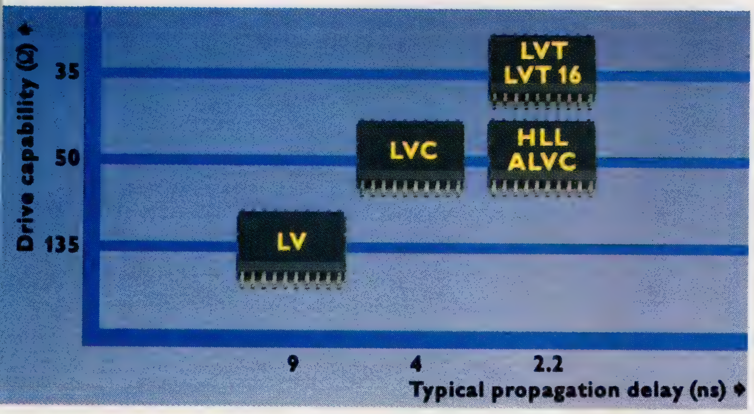
Integrated Device Technology, Inc.

CIRCLE NO. 96


Philips has the low voltage log
for whatever you have in min

It's a real eye-opener.

Six families of low voltage logic, each delivering a different combination of speed, drive and power consumption. No-one else can offer such a broad spectrum of solutions.



To help you focus on your job, all Philips low voltage log ICs are designed from scratch with industry-standard featur The BiCMOS LVT offers 3-5 V mixed mode capability, a HLL is quite simply the world's fastest 3 V CMOS logic.

Small designs are catered for with very small SSOP a TSSOP packages. And we haven't overlooked your need f security of supply. Alternate sourcing agreements are firm in place for all families except the unique HLL range.

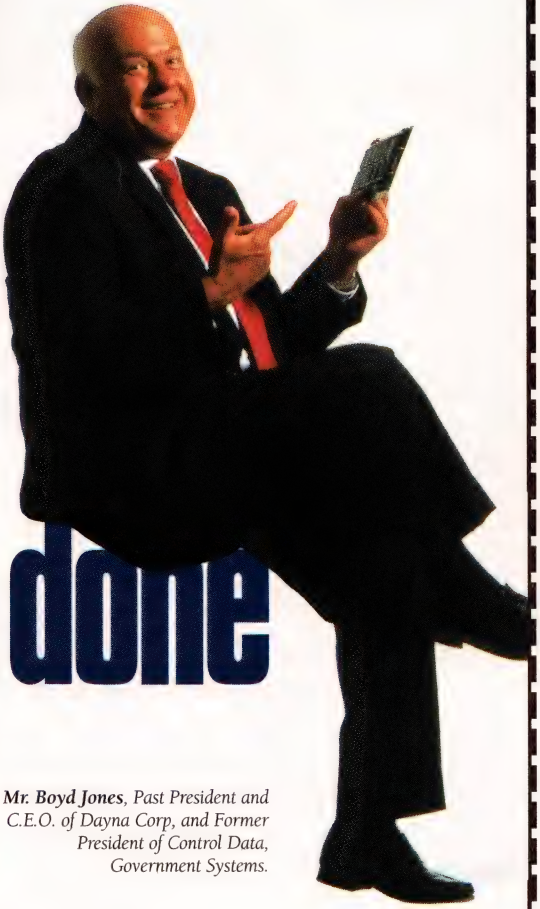
So if your design calls for low voltage logic, contact Phili You can be sure we'll have just what you're looking f

USA, call: 1-800-447-1500 ext. 1140.
Europe, fax: +31-40-724825, quoting 'LV logic.'
S.E. Asia, fax: +886 (2) 382-4485, quoting 'LV logic

Philips
Semiconductors

CIRCLE NO. 78

PHILIPS



'God created the world in six days. With the ACE-12™ He could have done it in three.'

Mr. Boyd Jones, Past President and C.E.O. of Dayna Corp, and Former President of Control Data, Government Systems.

Get 12 billion OPS for $3,000!

The *new* ACE-12™ from MSI gives you:

- The FASTEST P.C. reconfigurable computer card in the world
- The LOWEST PRICED P.C. reconfigurable computer card
- Plugs into any P.C.
- Complete Tool Suite

With the ACE-12™ reconfigurable computer card, you will cut your design time in half!

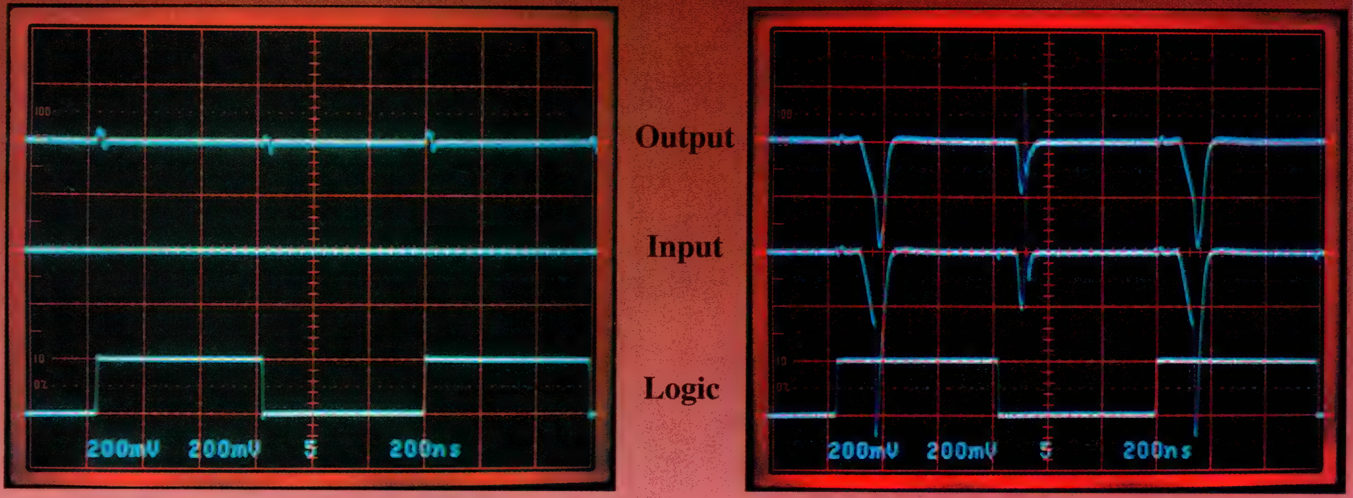
Give us one minute and we'll show you the future. Call: 1-800-YES-MSI4 (1-800-937-6744).

The Future is . . . MSI METALITHIC™ Systems, Inc.

Look for the future at the MSI booth at the DSP World Expo.

CIRCLE NO. 149

Switches Without Glitches.



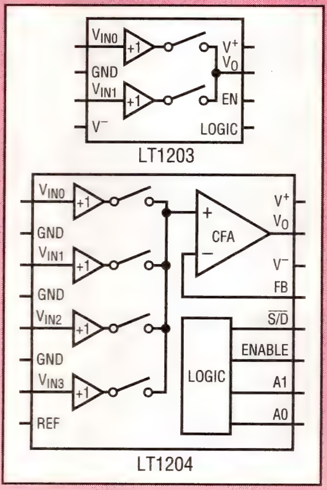
LT1203

CMOS MUX

LTC Video Multiplexers Have 90dB Isolation.

LTC's family of video multiplexers deliver professional quality solutions on your PC board without cascading switches to improve channel separation and isolation. The LT1203, LT1204 and LT1205 provide 90dB of isolation at 10MHz on real printed circuit boards. Forget those old switch buffers too, because all LTC multiplexers include buffers, are easily expandable and operate on ±5V to ±15V supplies. Switching glitches are almost invisible. The 2-input and 4-input LT1203/05 switch channels in only 25nsec and unlike CMOS switches, are virtually glitch-free at both output and input.

The LT1203/1205 are ideally suited for high speed graphics, multimedia, video routers or crosspoint applications delivering 150MHz bandwidth, 0.1dB gain flatness to 30MHz and Differential Gain/Phase of 0.02%/0.02° for true color fidelity.



For multiplexing where more output current is needed such as cable driving, the LT1204 4-input Video Multiplexer has an on-chip 75MHz Current Feedback Amplifier with 50mA output drive and 0.1dB gain flatness to 30MHz. A unique bootstrapping feature allows you to create larger multiplexers (8:1, 16:1) by just connecting the LT1204's outputs together, and you still get 90dB isolation at 10MHz on your PC board.

So, for multimedia, graphics or broadcast quality video, make LTC your first stop for ALL of your multiplexer needs. Pricing starts at $2.96 in 1000-piece quantities for the LT1203CS8. The LT1204CN is $4.78 and the surface mount LT1205CS starts at $5.06, both in 1000-piece quantities.

For details, contact Linear Technology Corporation, 1630 McCarthy Boulevard, Milpitas, California 95035/ 408-432-1900. For literature only, call **1-800-4-LINEAR.**

LINEAR
TECHNOLOGY

FROM YOUR MIND TO YOUR MARKET
AND EVERYTHING IN BETWEEN.

CIRCLE NO. 48

EDITED BY CHARLES H SMALL & ANNE WATSON SWAGER

PLD implements fast four-phase clock generator

SAID JACKSON, HAMBURG, GERMANY

The circuit in **Fig 1a** can clock pipelined logic in PLDs by an external agent at one-half the usual frequency. You can use this circuit when designing pipelined ALUs and switched-capacitor circuits. I used this circuit to drive a 40M-sample/sec CMOS flash ADC from an external 40-MHz crystal. All other implementations that we investigated (including shift registers and state machines) required an unacceptable 80-MHz external-clock input.

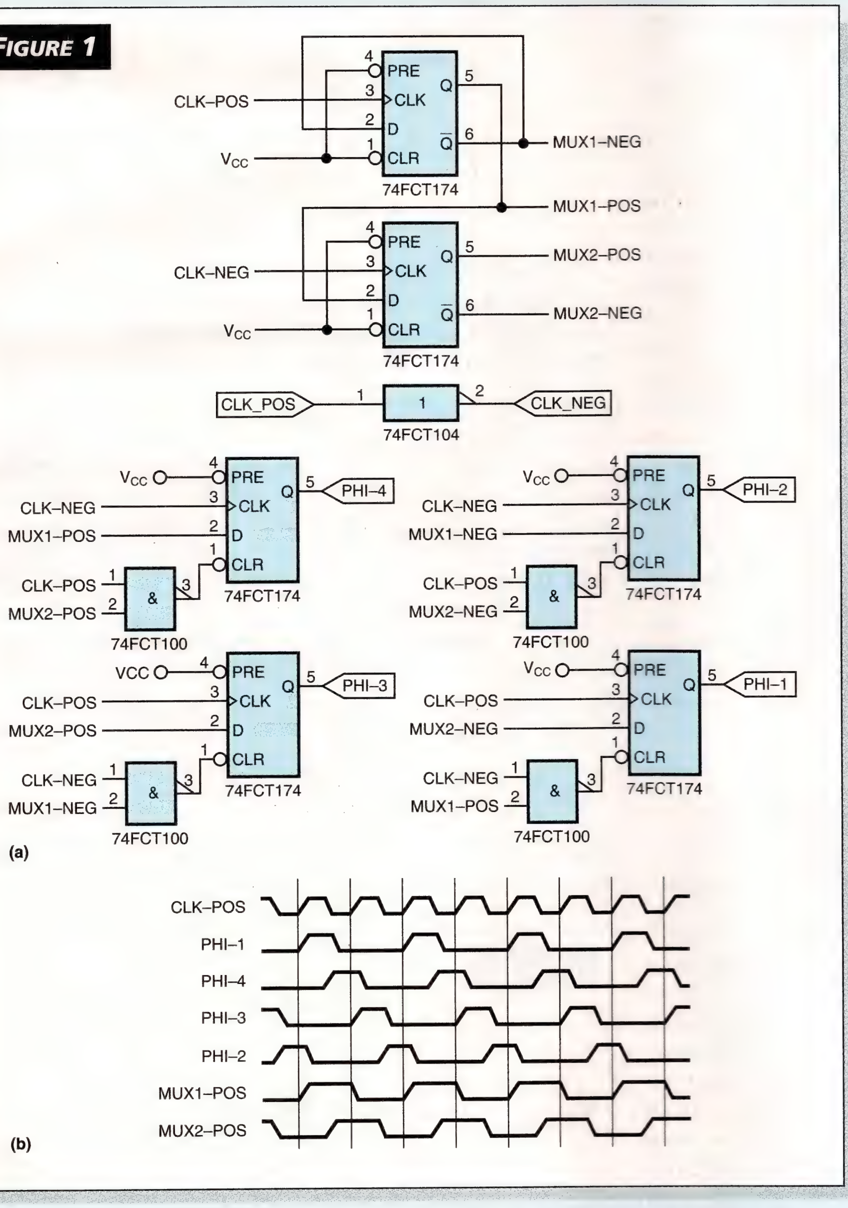
The circuit generates a fast four-phase clock usable in PLD, FPGA, gate-array, or other VLSI designs. The advantage, compared to standard circuit implementations, is that standard circuits change state only at the rising edge of the clock signal. Thus, standard circuits require master-clock frequencies that are twice as fast compared to circuits that change state at both rising and falling edges.

To implement the circuit, you need only PLDs that have an asynchronous product-term clocking feature that allows you to asynchronously reset the flip-flops. Examples include Lattice Semiconductor's ispLSI line or Intel's FlexLogic chips. Skew considerations mandate a VLSI, as opposed to discrete implementation, because both a buffered and an inverted version of the external clock signal are necessary.

The clock signal enters the circuit as CLK-POS, which the circuit inverts into CLK-NEG. The skew between these two signals should be as small as possible; generating these signals with PLD product terms guarantees that the skew is virtually zero. The circuit divides CLK-POS by two, and a register delays the result by one-half clock cycle. The new CLK-POS/2 and -NEG/2 signals are called MUX1-NEG and –POS and MUX2-NEG and –POS and have a 90° phase shift with respect to each other. PHI-1 goes high by latching MUX2-NEG with the rising edge of CLK-POS. The circuit puts the rising edge of CLK-NEG with MUX1-POS through an AND gate, which resets PHI-1 asynchronously. Thus, PHI-1 stays high for only half a clock period. The remaining three PHIs follow this same scheme but are phase-shifted by 90, 180, and 270°, respectively. The result is a four-phase overlapping clock generator.

The propagation delay of the NAND gates produces phase overlap. Although the rising edges of the PHI clocks follow CLK-POS and -NEG signals directly, the propagation delay of the NAND gate delays the falling edges. You can carefully design the PLD to remove this overlap. Because group delays within a single VLSI chip match closely, you can use combinatorial delay methods to shift the signals to the desired nonoverlapping positions. (DI #1611) EDN

FIGURE 1



This fast four-phase clock generator (a) runs at half the speed of other possible implementations. There is some overlap of the four clocks (b) that you can remove using careful PLD design.

To Vote For This Design, Circle No. 377

Protection feature enhances boost converter

DIMITRY GODER, LINEAR TECHNOLOGY CORP, MILPITAS, CA

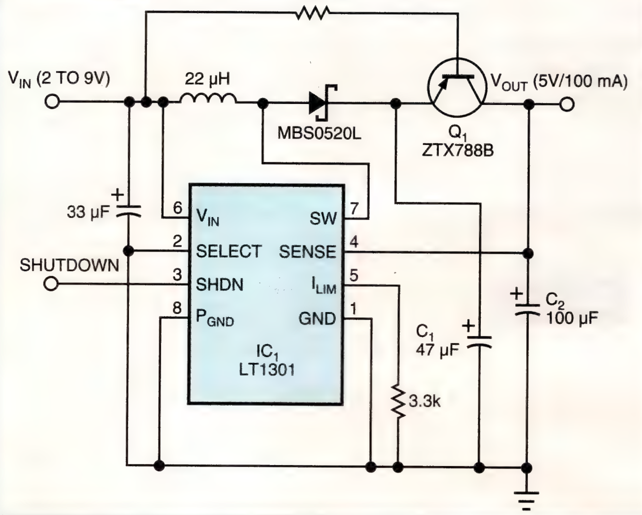
A boost-topology switching regulator is the simplest solution for converting a two- to three-cell input to a 5V output. Unfortunately, boost regulators have several inherent disadvantages, including a lack of short-circuit protection and shutdown capability. In some battery-operated products, external chargers or adapters can raise the battery voltage to a potential higher than the 5V output. Because of this increase, a boost converter can't maintain regulation because the high input voltage feeds through the diode to the output.

The circuit in **Fig 1** overcomes these problems. IC_1 is a conventional boost converter that preserves simplicity and high efficiency in the boost mode. Q_1 adds the features of short-circuit limiting, true shutdown, and regulation under high-input-voltage conditions.

When the input voltage is lower than 4V and the regulator is enabled, the circuit drives Q_1's emitter above its base and saturates the transistor. As a result, the voltages on C_1 and C_2 are roughly the same, and the circuit operates as a conventional boost regulator. If the input voltage increases above 4V, the internal error amplifier acts to keep the output at 5V and boosts the voltage on C_1 to a level about 1V above the input. This voltage controls Q_1 to provide the desired output, and the transistor operates as a linear pass element. The output does not experience any abrupt changes during the switchover between step-up and -down modes because the same error amplifier monitors the output in both modes.

The circuit's efficiency peaks at approximately 88% with an input of 4.25V. At 4.25V, Q_1 begins to operate in a linear mode with an attendant roll-off of efficiency for higher input voltages. When operating in the boost mode, efficiency is between 82 and 88% for input voltages as low as 2V.

FIGURE 1



For input voltages below 4V, this circuit operates as a conventional boost regulator. When the input rises beyond 4V, the circuit operates in a linear step-down mode.

Pulling IC_1's shutdown pin high turns off the circuit. IC_1 ceases switching, and Q_1 automatically turns off and fully disconnects the output. Q_1 also provides overload protection. When the output shorts, IC_1 operates in a cycle-by-cycle current limit. The short-circuit current, which typically reaches 200 mA, depends on IC_1's maximum switch current and Q_1's gain. Q_1 can withstand overload for several seconds before heating up. For sustained faults, you must also consider the thermal effects on Q_1. (DI #1605)

To Vote For This Design, Circle No. 378

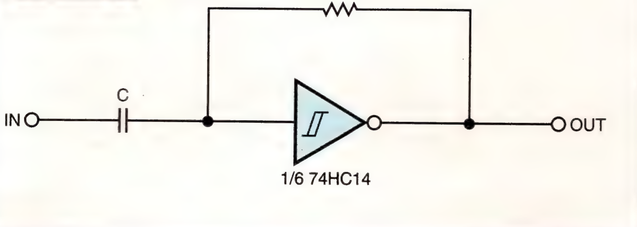
Single gate synchronizes clock

PHIL HARVEY, TECHNOLOGY INTEGRATION INC, BEDFORD, MA

The deceptively simple circuit in **Fig 1** harbors formidable power. Consider when you have a data-clock input to your system for an existing serial data stream. Then, your system people surprise you with a new serial data source after your real-estate budget is used up. You can synchronize the new signal to the clock and assign the data to an unused input bit without unduly burdening your software engineers. But, if the gadget that supplies the data clock goes haywire, your new signal dies with it; that is, unless you supply the clock and synchronize it to the functioning existing clock by using a spare inverter.

With its input grounded, a single inverter becomes the familiar relaxation oscillator and generates a square wave.

FIGURE 1



A single spare inverter, a resistor, and a capacitor can synchronize two clock signals.

RF TRANSFORMERS

Over 80 off-the-shelf models...
3KHz- 2000MHz from **$1**

Having difficulty locating RF or pulse transformers with low droop, fast risetime or a particular impedance ratio over a specified frequency range?.... Mini-Circuits offers a solution.

Choose impedance ratios from 1:1 to 36:1, in connector, TO-, flatpack, surface-mount, or pin versions (plastic or metal case built to meet MIL-T-21038 and MIL-T-55631 requirements*). Coaxial connector models are offered with 50 and 75 ohm impedance; BNC standard, other types on request.

Ultra-wideband response achieves low droop and fast risetime for pulse applications. Ratings up to 1000M ohms insulation resistance and up to 1000V dielectric voltage. For wide dynamic range applications involving up to 100mA primary current, use the T-H series. Fully detailed data appear in our 740-pg RF/IF Designer's Handbook.

Need units in a hurry?... all models are covered by our exclusive one-week shipment guarantee.
Only from Mini-Circuits.

*units are not QPL listed.

Mini-Circuits®

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661

For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM • MINI-CIRCUITS' 740- pg. HANDBOOK.

*CUSTOM PRODUCT NEEDS...**Let Our Experience Work For You.***

CIRCLE NO. 64

F 71 Rev F

However, a clock driving the input at about the same rate reproduces itself (inverted) with only CMOS propagation delays. An additional inverter at either end restores the phase. The frequency margin over which you can assure synchronization is much wider than the expected variation in free-running frequency. The margin is wide because the free-running oscillator's input pingpongs between the two Schmitt-trigger thresholds, typically 1 Vp-p. The CMOS drive levels of 5 Vp-p provide so much overdrive that, if signals were nicely symmetrical, synchronism is assured down to one-fifth of the free-running frequency. Unfortunately, you can't be sure of such symmetry, but a factor of two is safe. The free-running rate is not terribly accurate, but high accuracy is not always needed just to keep the data flowing.

If the feedback resistor R is large, any normal, low source impedance is a practical short circuit when the input signal dies. In particular, if the input voltage goes to the positive rail, it's also a short circuit. If you use this circuit, don't forget to protect the input from external transients, opens, and shorts. (DI #1606)

To Vote For This Design, Circle No. 379

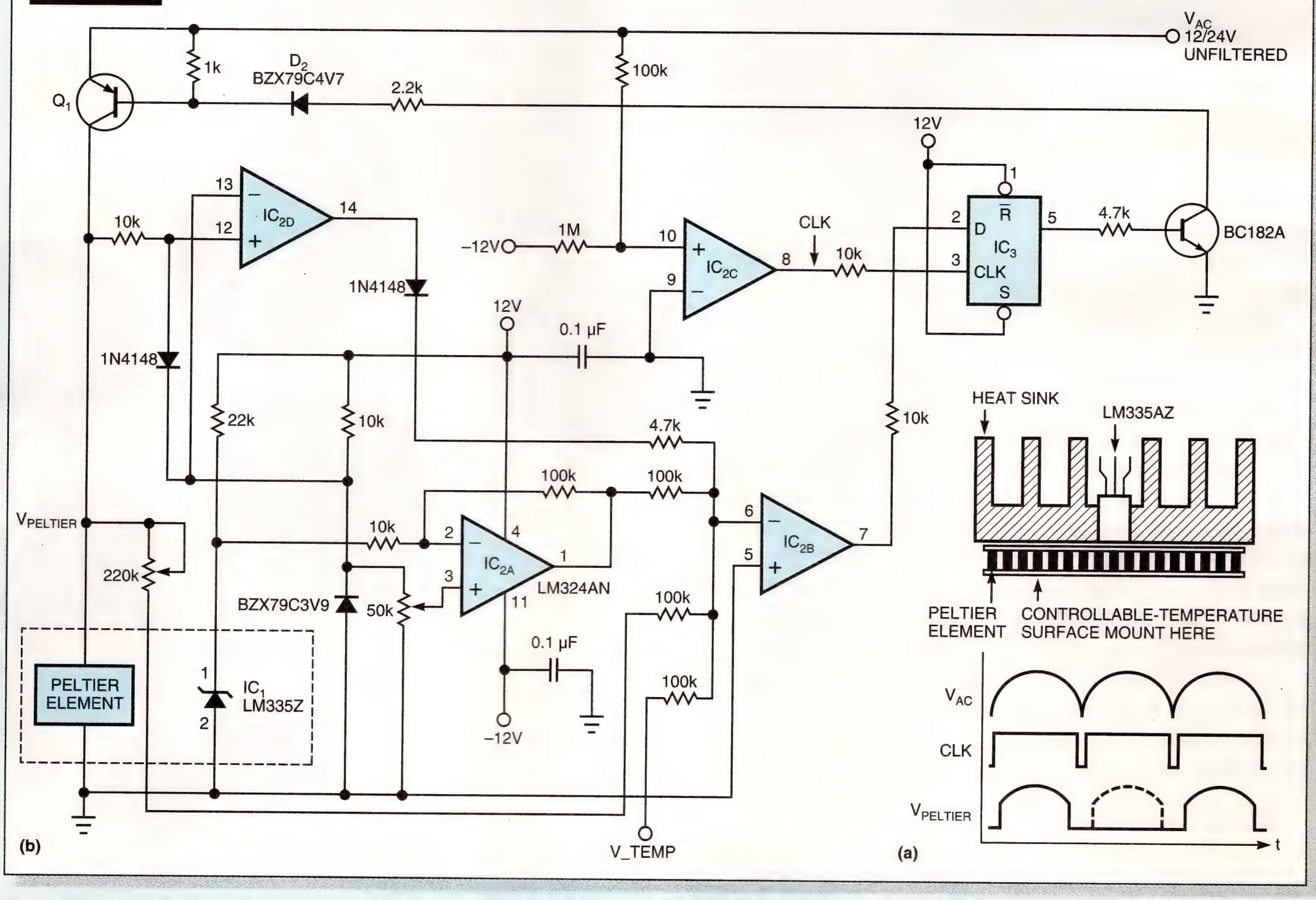
Peltier element controls itself

DMITRII LOUKIANOV, INTEL CORP, MOSCOW, RUSSIA

Peltier elements, or semiconductor heat pumps, combined with heat sinks are a designer's choice when controlled low temperature is required for CCDs and high-density ICs. These devices are suitable for device temperature cycling in reliability tests and for regular cooling. Because mounting inexpensive temperature sensors directly onto the controlled temperature surface isn't easy, a simple circuit (**Fig 1b**) provides the control. The circuit is successful because the Peltier element is a reciprocal device.

When current flows through the element's cells, the element pumps the heat from one surface to another, resulting in a temperature difference. But the element also generates a

FIGURE 1

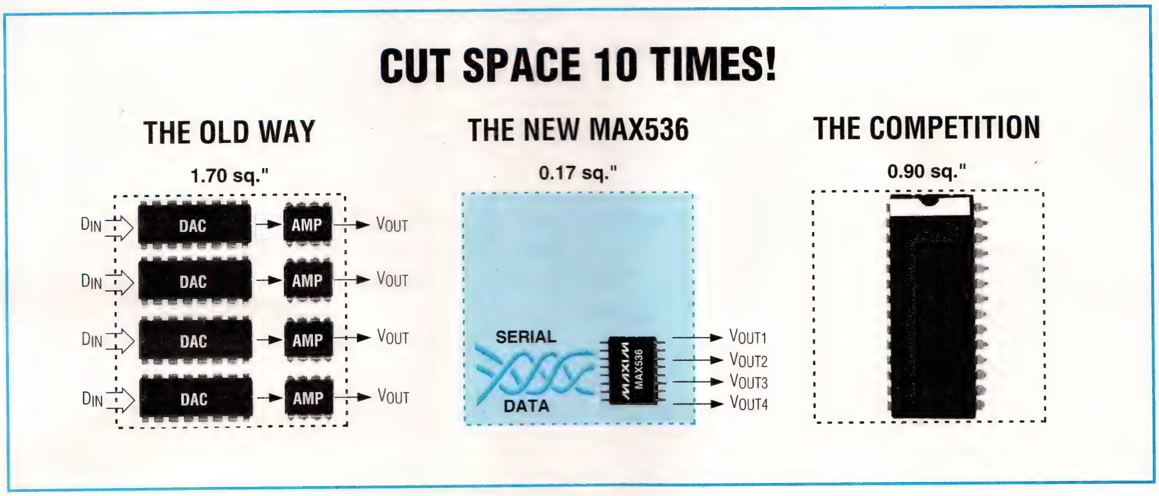


To measure and control temperature of a surface (a), this circuit (b) measures heat-sink temperature and subtracts the temperature difference indicated by the Peltier device.

WORLD'S SMALLEST MOST ACCURATE QUAD 12-BIT VOUT DAC

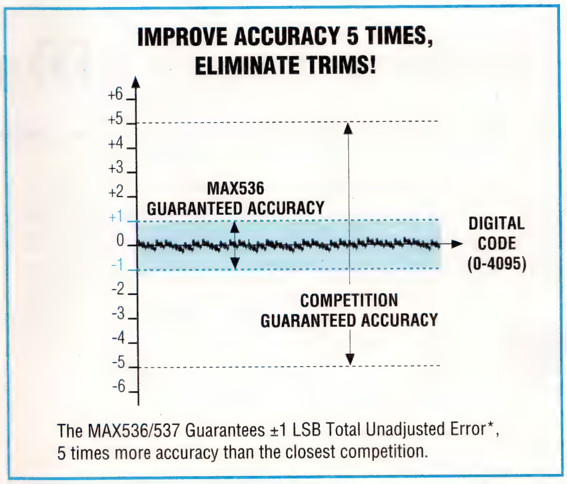
Cut Space, Eliminate Costly Trims!

The MAX536/MAX537 is ideal for servo-control, offset/gain-adjust, and other applications where high precision and small form-factor are critical. 12-bit montonicity, ±$^1/_2$LSB relative accuracy, and ±1LSB Total Unadjusted Error* (MAX536) are guaranteed with no zero- or full-scale adjustments. The four DACs can be updated either independently or simultaneously via a single command register, and the serial interface is fully compatible with SPI™. QSPI™, and MicroWire™.



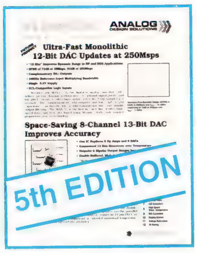
CUT SPACE 10 TIMES!

- ◆ **3-Wire Serial Interface Frees µP I/O Pins**
- ◆ **±1 LSB TUE* Eliminates Trims**
- ◆ **16-Pin SOIC/DIP Save Space**
- ◆ **±5V Supply Operation (MAX537)**
- ◆ **Low-Noise Precision Output Buffers On-Chip**
- ◆ **Parallel Versions Also Available (MAX526/MAX527)**



IMPROVE ACCURACY 5 TIMES, ELIMINATE TRIMS!

The MAX536/537 Guarantees ±1 LSB Total Unadjusted Error*, 5 times more accuracy than the closest competition.



ANALOG DESIGN SOLUTIONS

Ultra-Fast Monolithic 12-Bit DAC Updates at 250Msps

Space-Saving 8-Channel 13-Bit DAC Improves Accuracy

5th EDITION

FREE D/A Converter Design Guide—*Sent Within 24 Hours!*
Includes: Data Sheets and Cards for Free Samples

CALL TOLL FREE 1-800-722-8266
For a Design Guide or Free Sample
MasterCard® and Visa® are accepted for Evaluation Kits or small quantity orders.

MAXIM

Accredited by the Dutch Council for Certification
Quality Assurance Certification
REGISTRAR ACCREDITATION BOARD
ISO 9001
Certificate Number: 30337

Distributed by Arrow, Bell, CAM RPC, Digi-Key, Elmo, Hamilton Hallmark, Nu Horizons, and Zeus. Authorized Maxim Representatives: **AL,** EnVision; **AZ,** Techni Source Inc.; **CA,** (Northern California) Maxim Integrated Products, (Southern California) Mesa, Infinity Sales, Inc.; **CO,** Component Sales; **CT,** Comp Rep Associates; **DE,** TAI Corporation; **FL,** Sales Engineering Concepts; **GA,** EnVision; **ID,** E.S. Chase; **IL,** Industrial Representatives, Inc; **IN,** Technology Marketing Group; **IA,** JR Sales Engineering, Inc.; **KS,** Delltron; **LA,** Maxim Integrated Products, Inc.; **MD,** Micro-Comp, Inc.; **MA,** Comp Rep Associates; **MI,** Micro Tech Sales; **MN,** Mel Foster Technical Sales, Inc.; **MO,** Delltron; **MT,** E.S. Chase; **NE,** Delltron; **NH,** Comp Rep Associates; **NJ,** Parallax, TAI Corporation; **NM,** Techni Source Inc.; **NY,** Parallax, Reagan/Compar; **NC,** EnVision; **OH,** Lyons Corporation; **OK,** Maxim Integrated Products, Inc.; **OR,** E.S. Chase; **PA** (Pittsburgh area) Lyons Corporation, (Philadelphia area) TAI Corporation; **SC,** EnVision; **TX,** Maxim Integrated Products, Inc.; **UT,** Luscombe Engineering Co.; **VA,** Micro-Comp, Inc.; **WA,** E.S. Chase; **WI,** Industrial Representatives, Inc.
Distributed in Canada by Arrow. Authorized Maxim Representative in Canada: Tech Trek.

Austria, Allmos Electronics **Belgium**, Master Chips **Denmark**, Arrow-Exatec A/S **Finland**. Yleiselektroniikka Oy, **France**, Maxim France, *France/Distributors*: Maxim France, ASAP **Germany**, Maxim GmbH *Germany/Distributors:* Maxim GmbH, Spezial Electronic KG **Ireland**, FMG Electronics **Italy**, Consystem S.r.l., *Italy/Distributor:* Esco Italiana Electronics Supply **Netherlands**, Koning En Hartman **Norway**, Berendsen Technology **Poland**, Uniprod, Ltd. **Portugal**, ADM Electronics, S.A. **Spain**, ADM Electronics S.A. **Sweden**, Egevo AB **Switzerland**, Laser & Electronics AG **Turkey**, Interex (U.S.A.) **U.K.** Maxim Integrated Products (U.K.), Ltd., *U.K./Distributors*. Maxim Integrated Products (U.K.), Ltd., 2001 Electronic Components, HB Electronic

Maxim is a registered trademark of Maxim Integrated Products. © 1994 Maxim Integrated Products

CIRCLE NO. 155

voltage proportional to that difference when no current is applied. For typical 12 and 24V elements, the voltage is about 0.1 to 0.3V/K. You can determine the actual controlled surface temperature by measuring that of another surface, such as the heat sink, and subtracting the Peltier element's difference from it (**Fig 1a**).

Because bulky elements are slow, you can power them with unregulated and rectified 50/60 Hz and 12/24-ac voltages. The circuit measures heat-sink temperature using IC_1, which is an LM335 10-mV/K linear thermometer. IC_{2A} amplifies IC_1's output to 0.1 V/K and subtracts the 2.73V background signal to center the output around 0°C. IC_{2B} compares this voltage to the voltage across the Peltier element during the zero crossing of the ac input, and IC_3 latches the result. This result is valid through the next 10-msec cycle and determines whether the circuit applies the next half-wave to the Peltier element. IC_{2C} provides the clock for IC_3 when the ac source is at 1.2V. If the absolute voltage generated by the Peltier element exceeds 5V, IC_{2D} switches the current off to protect the element from stress.

A simple Darlington switch, Q_1, conducts only when the half-wave voltage is greater than 5V, as determined by D_2, and provides about a 2-msec gap between the current-off and Peltier voltage sampling. You should choose Q_1 so that its current and voltage ratings are greater than or equal to the Peltier element. In this case, IC should be greater than 6 to 8A, and V_{CE} should be greater than 30 to 50V. For a 12V, 5A Peltier element, you can use BDX34 by SGS-Thomson, but the TIP135 and 145 by Texas Instruments are also suitable. The temperature offset input V_Temp provides for external control. Although this circuit with the unipolar switch provides cooling only, you can build a controller for both negative and positive temperature swings. You build this controller by powering the Peltier element with a triac rectifier, using the positive output for cooling and negative for heating. IC_3 should still control the on/off state of the rectifier. No other circuit modifications are necessary, except for protection around IC_{2D}, which must take the absolute value of the Peltier voltage. (DI #1607)

To Vote For This Design, Circle No. 380

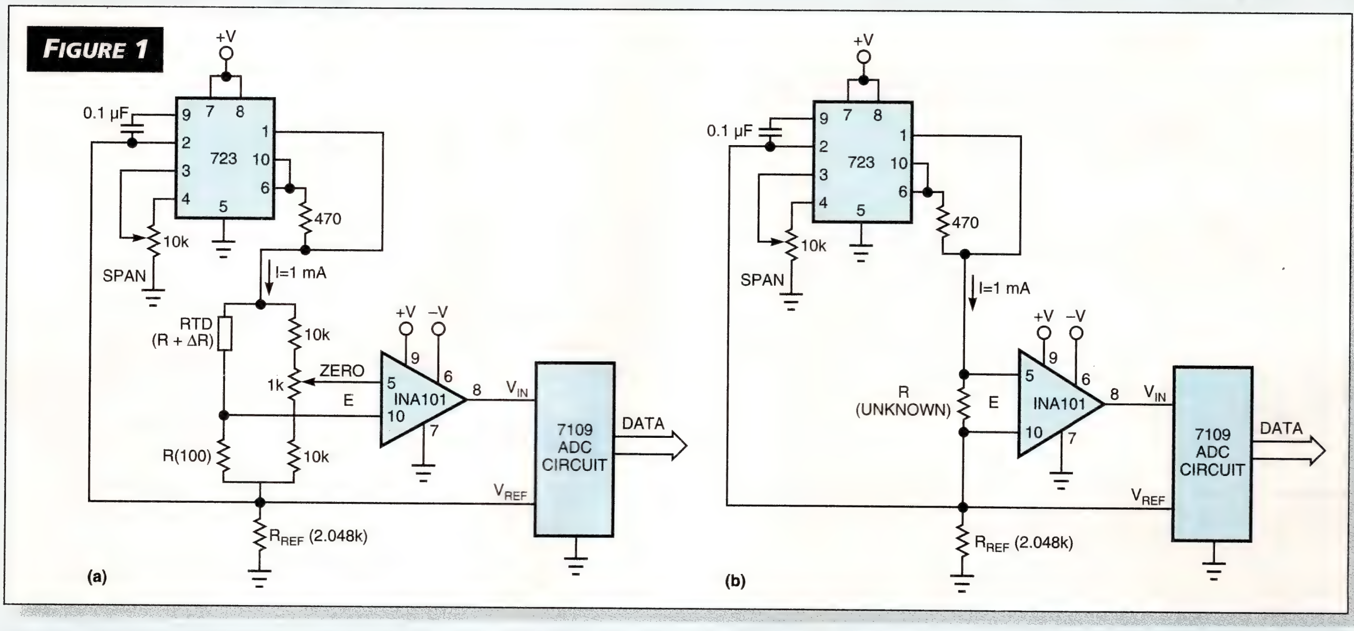
ADC's reference improves RTD measurements

R JAYAPAL, BHARAT HEAVY ELECTRICALS LTD, TIRUCHIRAPALLI, INDIA

Temperature measurements using RTDs (resistance-temperature detectors) generally employ bridge circuits with stable power supplies for signal conditioning. Unfortunately, this scheme generally produces nonlinear outputs. A linear bridge configuration that uses two identical current sources depends on the accuracy of matching the sources.

Fig 1a shows a linear bridge configuration with a single current source. The circuit eliminates the nonlinearity prob-

FIGURE 1



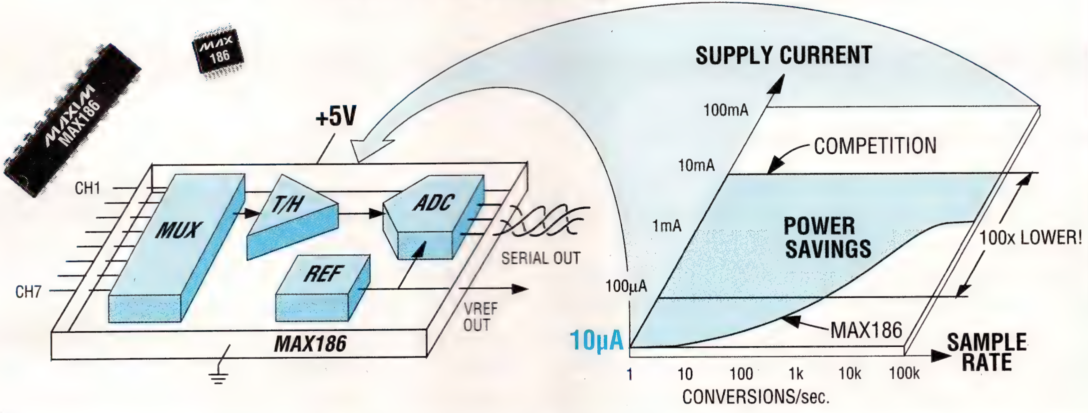
For temperature measurements using RTDs, this linear-bridge configuration (a) uses a single current source to eliminate the difficulty of matching two sources. The circuit overcomes it's dependency on the accuracy of the single source by using the ADC's reference input for compensation. The circuit makes precise resistance measurements using the same techniques.

LOWEST POWER SERIAL 12-BIT ADCs DRAW 10µA AT 5V

100 Times Lower than the Next Best!

The MAX186/MAX188 A/D converters sample 8 single-ended or 4 differential inputs with a throughput rate as high as 133ksamples/sec. At lower rates, supply current drops below 10µA, including reference current! For single-channel applications the MAX187/MAX189 come in space-saving 8-pin packages.

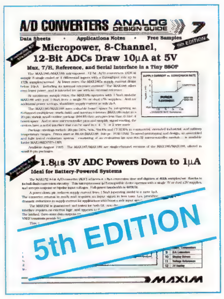
Save Power & Space!



Choose Your 5V µPower 12-Bit ADC

Part #	Output Format	Input Channels	Ref	Sample Rate	Power Down (max)	Pins*	Price†	Call For EV Kit:
MAX186	Serial	8	INT	133ksps	10µA	20	$8.95	MAX186EVSYS
MAX187	Serial	1	INT	75ksps	10µA	8	$7.45	MAX187EVSYS
MAX188	Serial	8	EXT	133ksps	10µA	20	$8.45	MAX186EVSYS
MAX189	Serial	1	EXT	75ksps	10µA	8	$6.95	MAX187EVSYS
MAX191	Parallel	1	INT	100ksps	50µA	24	$9.60	MAX191EVSYS

** Package Options Include DIP, SOIC, and SSOP*
† 1000-up Recommended Resale, FOB, USA


A/D CONVERTERS ANALOG DESIGN GUIDE 7
Micropower, 8-Channel, 12-Bit ADCs Draw 10µA at 5V
1.8µs 3V ADC Powers Down to 1µA
5th EDITION
MAXIM

FREE A/D Converter Design Guide—*Sent Within 24 Hours!*
Includes: Data Sheets and Cards for Free Samples

CALL TOLL FREE 1-800-998-8800
For a Design Guide or Free Sample
MasterCard® and Visa® are accepted for Evaluation Kits or small quantity orders.

MAXIM

Accredited by the Dutch Council for Certification
ABS Quality Evaluations, Inc. Quality Assurance Certification
REGISTRAR ACCREDITATION BOARD
ISO 9001
Certificate Number: 30337

Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086, (408) 737-7600, FAX(408) 737-7194.

Distributed by Arrow, Bell, Digi-Key, Elmo, Hamilton Hallmark, and Nu Horizons. Authorized Maxim Representatives: **AL,** M-Squared, Inc.; **AZ,** Techni Source Inc.; **CA,** Mesa, Pro Associates, Inc., Infinity Sales, Inc.; **CO,** Component Sales; **CT,** Comp Rep Associates; **DE,** TAI Corporation; **FL,** Sales Engineering Concepts; **GA,** M-Squared, Inc.; **ID,** E.S. Chase; **IL,** Heartland Technical Marketing Inc.; **IN,** Technology Marketing Group; **IA,** JR Sales Engineering, Inc.; **KS,** Delltron; **LA,** BP Sales; **MD,** Micro-Comp, Inc.; **MA,** Comp Rep Associates; **MI,** Micro Tech Sales; **MN,** Mel Foster Technical Sales, Inc.; **MS,** M-Squared, Inc.; **MO,** Delltron; **MT,** E.S. Chase; **NE,** Delltron; **NV** (Reno, Tahoe area only) Pro Associates, Inc.; **NH,** Comp Rep Associates; **NJ,** Parallax, TAI Corporation; **NM,** Techni Source Inc.; **NY,** Parallax, Reagan/Compar; **NC,** M-Squared, Inc.; **OH,** Lyons Corporation; **OK,** BP Sales; **OR,** E.S. Chase; **PA** (Pittsburgh area) Lyons Corporation, (Philadelphia area) TAI Corporation; **SC,** M-Squared, Inc.; **TN,** M-Squared, Inc.; **TX,** BP Sales; **UT,** Luscombe Engineering Co.; **VA,** Micro-Comp, Inc.; **WA,** E.S. Chase; **WI,** Heartland Technical Marketing, Inc.
Distributed in Canada by Arrow. Authorized Maxim Representative in Canada: Tech Trek.

Maxim is a registered trademark of Maxim Integrated Products. © 1993 Maxim Integrated Products

CIRCLE NO. 153

lem of constant voltage excitation as well as errors due to nonmatching current sources. The accuracy depends on the stability of the current source. To overcome this dependency, **Fig 1a** derives the dual-slope ADC's reference voltage from the IR drop. Any change in the constant current changes the reference voltage of the ADC, thereby compensating the current-source variation. Referring to **Fig 1a**,

$$E = \frac{I(R + R + \Delta R)}{2} - IR.$$

Thus,

$$E = \frac{I\Delta R}{2}.$$

In the dual-slope ADC circuit of **Fig 1a**,

$$\text{OUTPUT COUNTS} = K\frac{V_{IN}}{V_{REF}},$$

$$= K\frac{I\Delta R}{2IR_{REF}}, \text{ and}$$

$$= K\frac{\Delta R}{2R_{REF}},$$

where K is a constant. Hence, the digitized value is directly proportional to ΔR, which is proportional to temperature. Deviations in the excitation current have little effect on the output. You can extend the same technique to make precise resistance measurements. The circuit in **Fig 1b** can measure up to 2 kΩ with a conversion factor of 1 mV/Ω. (DI #1609) EDN

To Vote For This Design, Circle No. 381

Variable gain control produces pure sine wave

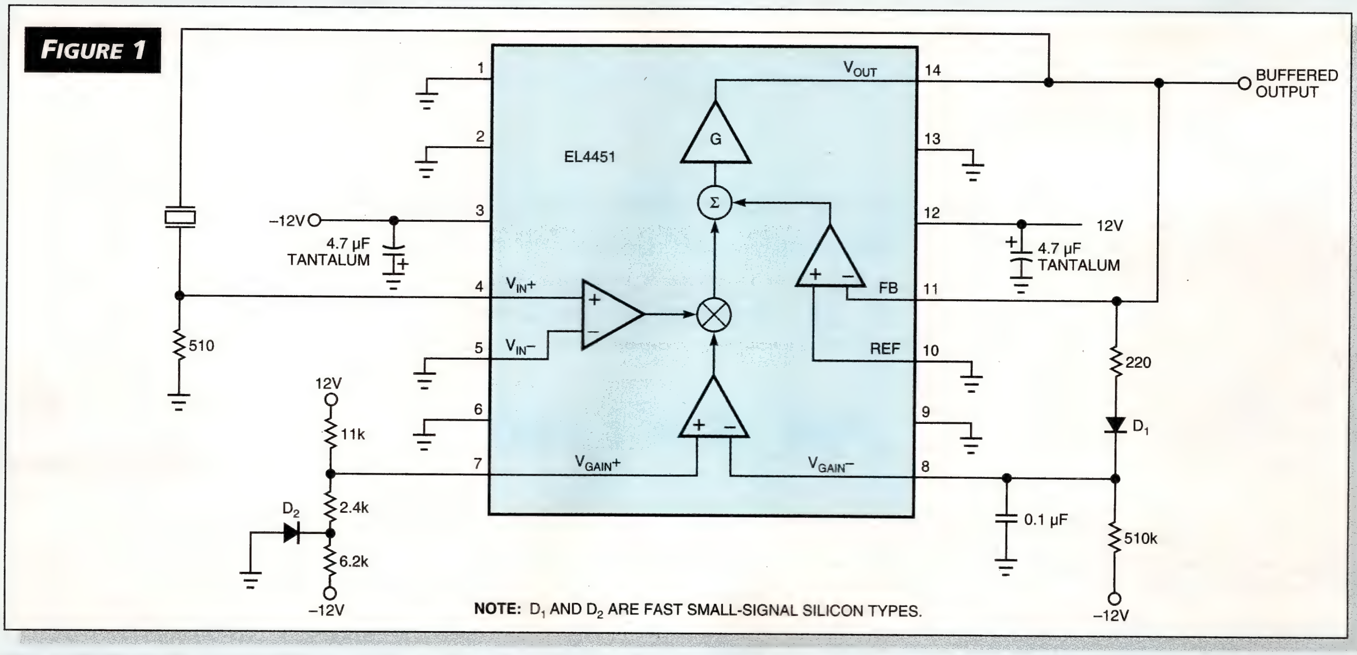
BARRY HARVEY, ELANTEC CORP, MILPITAS, CA

The circuit in **Fig 1** delivers a pure, buffered, and level-controlled sine wave. With no tuning requirements, the circuit works with all crystals up to about 30 MHz.

The typical crystal oscillator is an amplifier with a gain that is sufficiently higher than the loss of the crystal and feedback network and guarantees sustained oscillation. Because the amplifier's gain is greater than the network's loss, oscillation amplitude grows until the amplifier's output clips. The crystal filters the large harmonic content of the output and returns a fairly pure feedback sine wave to the amplifier. This circuit's main failings are its uncontrolled and unbuffered sinusoidal amplitude and its very high distortion levels—even when filtered by the crystal. Furthermore, the overload-recovery delays of the amplifier can warp the oscillation frequency away from the crystal's real resonant frequency, resulting in frequency error and drift.

Fig 1's circuit uses a variable-gain-control IC as the amplifier that continuously servos its gain to maintain a constant oscillation amplitude. The circuit connects the feedback terminal (FB) to the gain control's output. This connection establishes a gain range of 0 to 2 for a gain-control range of 0 to +2V. The gain-control inputs are differential and allow for flexible biasing and selection of phase sense. D_1 is a simple peak detector. If the output amplitude increases, the circuit applies an increasing, rectified, and filtered voltage to the negative-gain-control input, V_{GAIN-}, which reduces the ampli-

FIGURE 1



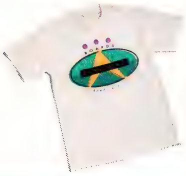
NOTE: D_1 AND D_2 ARE FAST SMALL-SIGNAL SILICON TYPES.

The variable-gain-control IC servos its gain to provide a constant oscillation amplitude and ultimately results in a low-distortion (0.22%) sine wave.

If you're not the biggest, you'd better be the fastest.

Fast products: **Laguna,** our newest VMEbus CPU board with an R4600 MIPS processor, delivers incredible speed and highly deterministic real-time performance. **Fast answers:** we're your one-stop shop, offering full hardware and software support for VxWorks™ and other real-time platforms. **Fast results:** our integrated support reduces your time to market.

Want immediate details on Laguna? Call 1-800-909-0264 for a faxed response within minutes.



Because faster is better, we'll send a
Really Cool Free T-shirt
to the first 1,000 callers.

Latest Product Release – Laguna!

HEURIKON CORP.®
A COMPUTER PRODUCTS COMPANY

Heurikon Corporation 8310 Excelsior Drive Madison, WI 53717-1938 (800) 356-9602 Voice (608) 831-5500 Fax (608) 831-4249 E-mail: info@heurikon.com

CIRCLE NO. 36

fier's gain. When the oscillation amplitude drops, the V_{GAIN-} input voltage drops, and the amplifier's gain increases to just that required for a controlled oscillation amplitude. The bias network at the positive-gain-control input V_{GAIN+} sets the output amplitude at 500 mV rms. D_2 compensates for the offset and temperature drift of D_1. Overtone-mode crystals require a series-tuned circuit to force oscillation to the right harmonic frequency.

With a 2-MHz crystal, output distortion is a low 0.22%. The distortion at the input of the amplifier, V_{IN+}, is even lower at 0.03% because of the filtering by the crystal. You can us this amplifier input as an output, preferably after buffering i with a low-distortion amplifier. The narrowband spectral jitter is unmeasurable. The available spectrum analyzer has a 3-Hz filter; the spectral width of either output is only 14Hz wide and 90 dB down from the center frequency, corresponding to the filter's shape factor. (DI #1610)

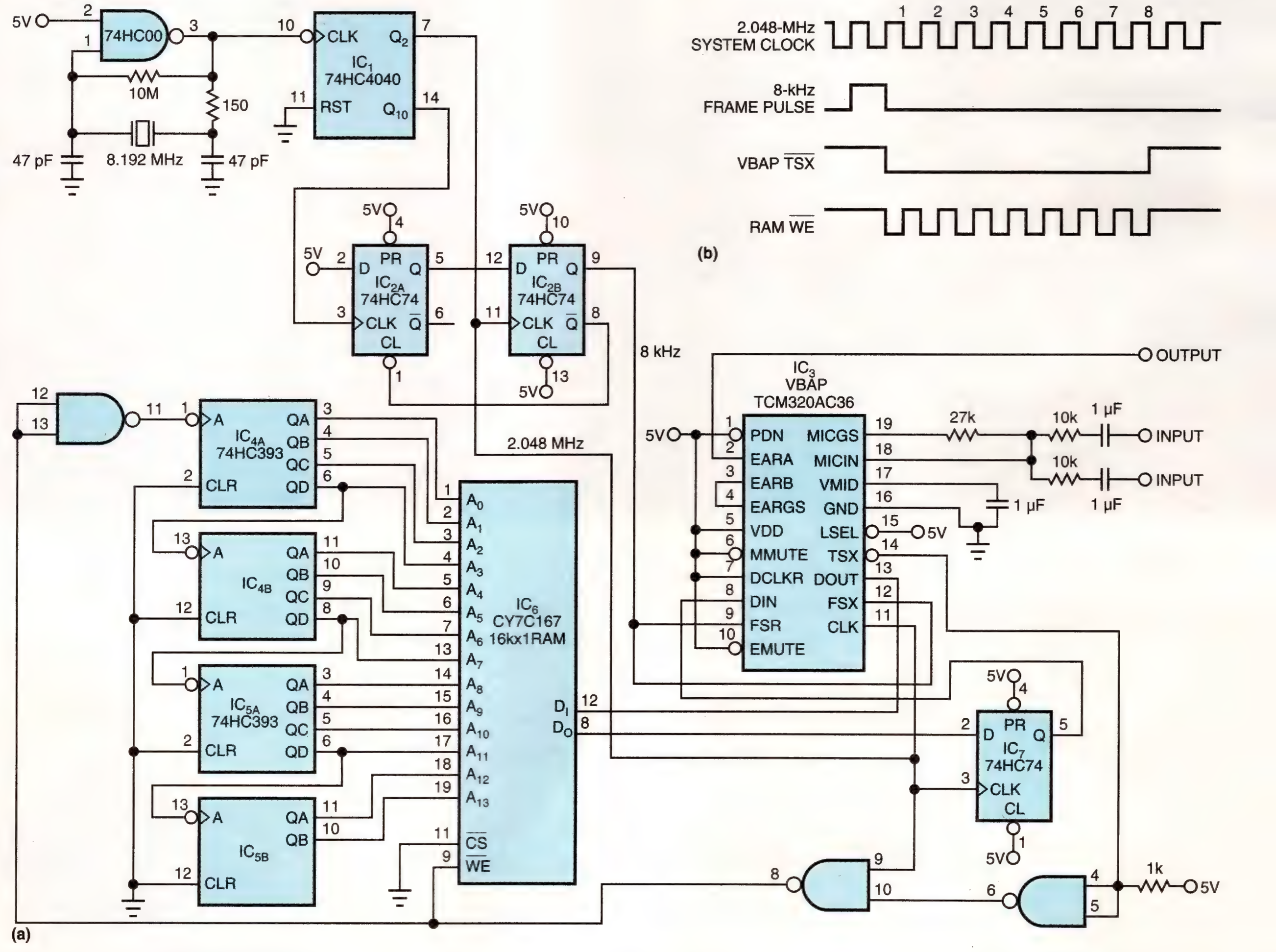
To Vote For This Design, Circle No. 382

Delay simulator debugs communications equipment

STAN SASAKI, LAKE OSWEGO, OR

Phone calls over satellite circuits experience a ¼-sec transmission delay in each direction. The low-cost circuit (around $20) in **Fig 1a** simulates this delay and provides hooks for inserting noise, echo, and other impairments. Designers debugging modems, fax machines, and other communication equipment can use this circuit to troubleshoot handshake timing and connection problems caused by transmission delays.

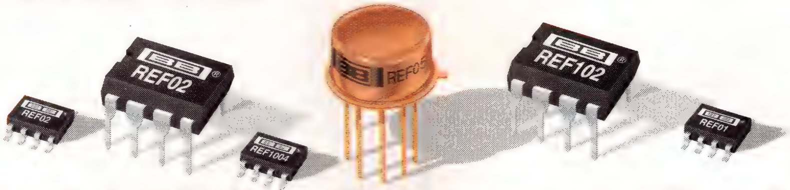
FIGURE 1



This $20 circuit (a) (b is a simplified timing diagram) simulates the ¼-sec delay inherent in satellite-transmission circuitry.

Check Our References!

- ✓ Higher accuracy
- ✓ Improved thermal stability
- ✓ 24-hour delivery
- ✓ More package options
- ✓ Industry's best overall value
- ✓ Low, low prices
- ✓ Drop-in replacements for industry standard models



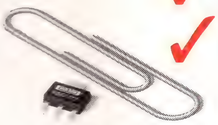
50+ Precision Voltage References and Regulators Improve Performance and Lower Costs

MODEL	OUTPUT/ ACCURACY	STABILITY	FEATURES	Price in 1000s
REF1004	1.235V±4mV 2.500V±20mV	20ppm/°C	10/20μA operating current	$1.55
REF02	5.0V±0.1%	8.5ppm/°C	0.005%/mA max load regulation	$2.15
REF05	5.0V±0.1%	8.5ppm/°C	25ppm/kHrs guaranteed long term stability	$15.30
REF01	10.0V±0.2%	8.5ppm/°C	5μVp-p noise	$2.15
REF10	10.00V±5mV	1ppm/°C	10ppm/kHrs long term stability	$15.73
REF101	10.00V±5mV	1ppm/°C	6μVp-p noise	$29.00
REF102	10.00±2.5mV	2.5ppm/°C	5ppm/kHrs long term stability	$2.95
REF200	100μA±0.5%	±25ppm/°C	dual floating current source/sink	$2.50

Check out our Voltage Regulators, too!

REG1117 series of positive regulators excel in SCSI active termination and portable power management applications. Check out these specs—

- ✓ 2.85V, 3.0V, 3.3V, 5.0V and adjustable models
- ✓ 2.85V device matched for SCSI-2 reequirements
- ✓ 800mA max output current
- ✓ compact SOT-223 package
- ✓ from **$1.85** in 1000s



Check out our Low Prices!

Check out our prices today! We offer competitive pricing that should make your boss and the bean counters happy. And, with our 24-hour delivery time—you get the references and regulators you need—when you need them.

Check this out...FREE Samples!

Check us out today! We support our reference and regulator lines with free samples, technical documentation, and comprehensive applications guides. Call **(800) 548-6132** or for immediate product information—use our **FAX***LINE*, **(800) 548-6133.**

BURR-BROWN ISO9001 CERTIFIED

BURR-BROWN®

Burr-Brown Corp. • P.O. Box 11400 • Tucson, AZ 85734

CIRCLE NO. 154

The 5V-only circuit uses a voiceband audio processor (VBAP) to convert a voiceband signal to a 64-kbps PCM data stream. A 16-kbit, first-in, first-out digital delay line delays the PCM stream by ¼ sec. The VBAP then converts the delayed stream back to a voiceband signal. The VBAP also performs the same filtering and coding impairments that are encountered in a toll-quality telephone circuit.

The ripple-counter IC_1 divides the 8.192-MHz crystal oscillator's output to generate the 2.048-MHz system clock. IC_2 synchronizes the 8-kHz tap of IC_1 to generate an 8-kHz frame pulse that drives the VBAP (IC_4). The frame pulse commands the VBAP to convert the analog input signal at MICGS to an 8-bit serial output word at DOUT and converts the 8-bit serial input word at DIN to the analog output signal at EARA. Data clocks into and out of IC_3 at 2.048 MHz in bursts of 8 bits/frame. IC_3 generates a gating signal, TSX, that goes low for the duration of each 8-bit serial transfer.

IC_6, a 16-kbit×1-bit RAM with separate data input and output pins, implements the digital delay. IC_4 and IC_5 form a 14-bit binary address counter that counts through the range of the RAM. The circuit gates TSX with the system clock to generate bursts of eight write strobes to the RAM to generate clocks that increment the address counter. IC_7 latches the delayed data before the new data overwrites it. IC_3 clocks the input data on the falling edge of the system clock.

IC_3 provides a summing node at MICIN and enables multiple inputs. You can add the input signal with a noise source to simulate both the delay and noise in the satellite channel. In this configuration, the reference-signal (0 dB) level at the inputs and outputs is 375 mV rms. The output impedance is a few ohms, and the output is offset to one-half the supply voltage, or 2.5V. You can also configure the VBAP for a balanced differential output.

Fig 1a's circuit implements the delay in a single direction. You can add a second channel to simulate the return circuit by using another 16-kbit×1-bit RAM, the other half of IC_7, and another VBAP chip. You can reuse all the clocking, gating, and address counters for the second channel. With a delay line connected in each conversation path, feeding back part of each analog output through the summing input of the other delay line simulates the ½-sec, round-trip echo in a satellite circuit. You can also use other RAM widths and depths to add more channels or simulate longer (double satellite hops) or shorter (terrestrial-cable) delays. (DI #1608) EDN

To Vote For This Design, Circle No. 383

How to use our bulletin board

This icon identifies those Design Ideas that have computer-readable material posted on *EDN*'s bulletin-board system (BBS). Call our free BBS at (617) 558-4241 (300/1200/2400 8,N,1). Not every Design Idea has downloadable material, but each one does have a BBS number printed at the end of it. If you'd like to comment on any Design Idea, include the number in the subject field of your message.

Sun Spark 5 workstations, AutoCad release 12,
THERE ARE
Cadence schematic capture, circuit simulation and
SOME PRETTY
PCB design software, Internet Connectivity,
BIG NAMES
Altera Max + Plus II Development Systems,
ON OUR BOARD.
PPG Electro Image Photoresist, Genrad.

compunetics, inc.
Engineering Systems Division
700 Seco Road, Monroeville, PA 15146 • (412) 373-8110
internet: jschmitt@well.sf.ca.us

CIRCLE NO. 19

IT'S NEW...
IT'S SMALL...
IT'S BRIGHT...
IT'S EFFICIENT.

IF YOU USE LAMPS,
IT'S FOR YOU.

FIND OUT.

Welch Allyn
Lighting Products Division
4619 Jordan Road, P.O. Box 187
Skaneateles Falls, NY 13153-0187
Phone: 315-685-4347
Fax: 315-685-2854

CIRCLE NO. 108

LINEAR TECHNOLOGY

DESIGN NOTES

Applicatons of the LT1366 Rail-to-Rail Amplifier – Design Note 89

William Jett and Sean Gold

The LT1366 is Linear Technology's first bipolar dual operational amplifier to combine rail-to-rail input and output operation with precision V_{OS} specifications. The LT1366 maintains precision specifications over a wide range of operating conditions. The device will operate with supply voltages as low as 1.8V and is fully specified for 3V, 5V, and ±15V operation. Offset voltage is typically 200μV when operating from a single 5V supply. Open-loop gain, A_{VOL}, is 2 million driving a 2kΩ load. Supply current is typically 375μA per amplifier. The combination of precision specifications and rail-to-rail operation makes the LT1366 a versatile amplifier, suitable for signal processing tasks that demand the widest possible common-mode range.

Precision Low Dropout Regulator

Microprocessors and complex digital circuits frequently specify tight control of power supply characteristics. The circuit shown in Figure 1 provides a precise 3.6V, 1A output from a minimum 3.8V input voltage. The circuit's nominal operating voltage is 4.75V ±5%. The voltage reference and resistor ratios determine output voltage accuracy, while the LT1366's high gain enforces 0.2% line and 0.2% load regulation. Quiescent current is about 1mA and does not change appreciably with supply or load. All components are available in surface mount packages.

The regulator's main loop consists of A1 and a logic level FET, Q1. The output is fed back to the op amp's positive input because of the phase inversion through Q1. The regulator's frequency response is limited by Q1's roll-off and the phase lead introduced by the output capacitor's effective series resistance (ESR). Two pole-zero networks compensate for these effects. The pole formed with R5 and C2 rolls off the gain set with the feedback network, while the pole formed with R7 and C3 rolls off A1's gain directly, which is the dominant influence on settling time. The zeros formed with R6 and C2, and R8 and C3 provide phase boost near the unity-gain crossover, which increases the regulator's phase margin. Although not directly part of the compensation, R9 decouples the op amp's output from the Q1's large gate capacitance.

A second loop provides a foldback current limit. A2 compares the sense voltage across R1 with 50mV referenced to the positive rail. When the sense voltage exceeds the

LT and LTC are registered trademarks and LT is a trademark of Linear Technology Corporation.

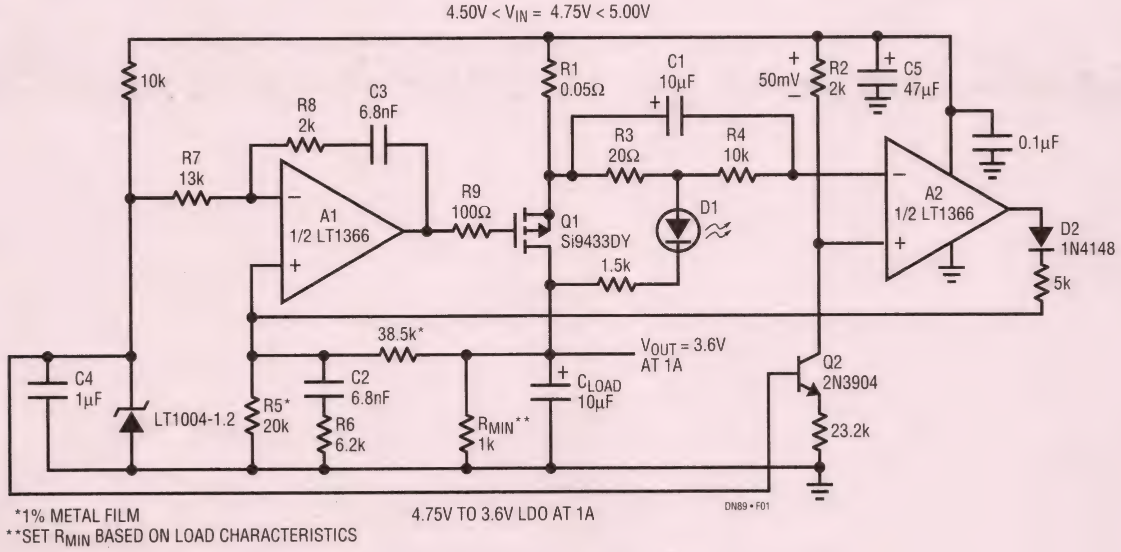


Figure 1. Precision 3.6V, 1A Low Dropout Regulator

reference, A2's output drives Q2's gate positive via A1. In current limit, the output voltage collapses and the current limit LED (D1) turns on causing about 30mV to drop across R3. A2 regulates Q1's drain current so that the deficit between the 50mV reference and the voltage across R3 is made up across the sense resistor. The reduced sense voltage is 20mV, which sets the current limit to about 400mA. As the supply voltage increases, the voltage across R3 increases, and the current limit folds back to a lower level. The current limit loop deactivates when the load current drops below the regulated output current. When the supply turns on rapidly, C1 bypasses the fold back circuit allowing the regulator to start-up into a heavy load.

Q1 does not require a heat sink. When mounted on a type FR4 PC board, Q1 has a thermal resistance of 50°C/W. At 1.4W worst case dissipation, Q1 can operate up to 80°C.

Single Supply, 1kHz, 4th Order Butterworth Filter

The LT1366 is also available as a quad op amp (LT1367), which is used in Figure 2 to form a 4th order Butterworth filter. The filter is a simplified state variable architecture consisting of two cascaded 2nd order sections. Each section uses the 360 degree phase shift around the 2 op amp loop to create a negative summing junction at A1's positive input.[1] The circuit has low sensitivities for center frequency and Q, which are set with the following equations:

$$\omega_0^2 = 1/(R1 \times C1 \times R2 \times C2)$$

where,

$$R1 = 1/(\omega_0 \times Q \times C1) \text{ and } R2 = Q/(\omega_0 \times C2).$$

The DC bias applied to A2 and A4, half supply, is not needed when split supplies are available. The circuit swings rail-to-rail in the passband making it an excellent anti-aliasing filter for A/Ds. The amplitude response is flat to 1kHz then rolls off at 80dB/decade.

Buffering A/D Converters

Figure 3 shows the LT1366 driving an LTC1288 two-channel micropower A/D. The LTC1288 can accommodate voltage references and input signals equal to the supply rails. The sampling nature of this A/D eliminates the need for an external sample-and-hold, but may call for a drive amplifier because of the A/D's 12µs settling requirement. The LT1366's rail-to-rail operation and low input offset voltage make it well suited for low power, low frequency A/D applications. In addition, the op amp's output settles to 1% in response to a 3mA load step through 100pF in less than 1.5µs.

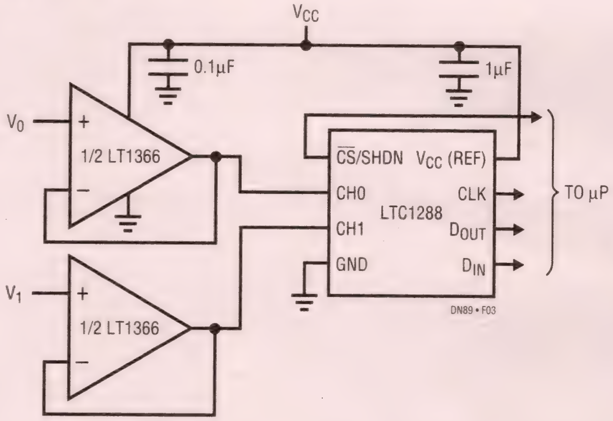


Figure 3. Two-Channel Low Power A/D

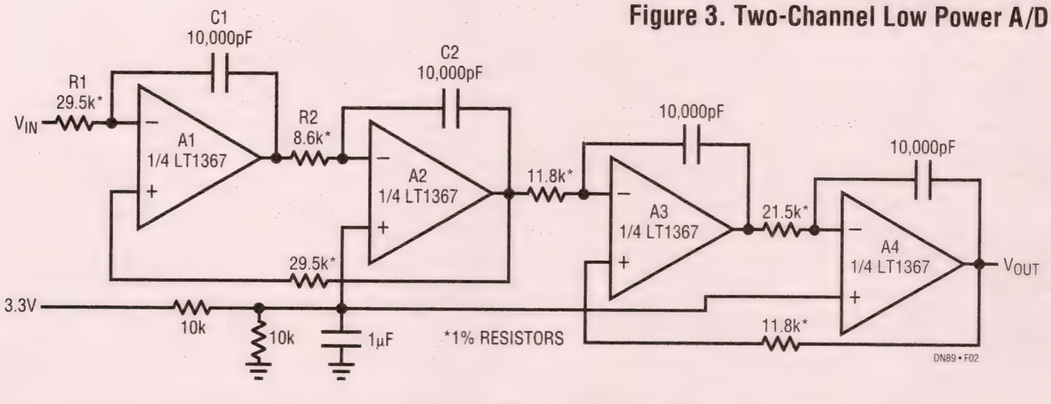


Figure 2. Single Supply Stage Variable Filter Using the LT1367

---

[1] James Hahn, "State Variable Filter Trims Predecessor's Component Count", *Electronics*, April 21, 1982.

For literature on our Operational Amplifiers, call **1-800-4-LINEAR**. For applications help, call (408) 432-1900, Ext. 456

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7487
(408) 432-1900 • FAX: (408) 434-0507 • TELEX: 499-3977

LT/GP 1094 190K • PRINTED IN THE USA

© LINEAR TECHNOLOGY CORPORATION 1994

POWER FOR Communications

Vicor Corporation, the leader in the component power industry, understands the needs of the telecommunications power system designer.

Our DC-DC converters and converter-based "total solutions" are designed to provide maximum flexibility and quick time to market, with safety agency approvals (UL, CSA, TÜV, VDE, BABT and UL94V0), a fixed form factor that enhances future upgrades and user definable outputs. Standard models are battery plant compatible, with 24V and 48V input versions for cellular and central switching applications. Our automated manufacturing facilities are ISO and BABT approved, and our converters have been field-proven through an installed base of over 3 million units, with demonstrated MTBFs as high as 20,000,000 hours.

In short, the inherent "plug and play" flexibility of our high density DC-DC converters gives you the power for communications...whenever and wherever required. And all Vicor products are supported by a global applications staff that's just a phone call away.

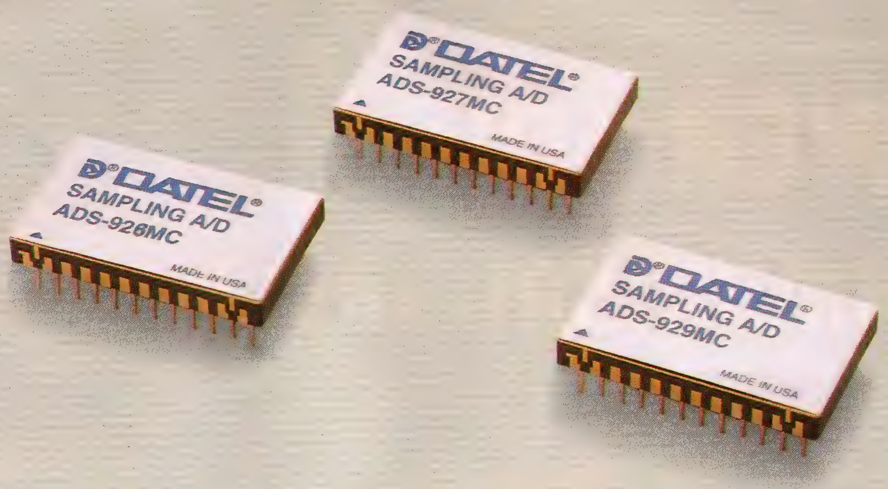
For more information on our complete line of component power products and total power solutions, give us a call at (800) 735-6200.

Component Solutions For Your Power System

Vicor Corporation 23 Frontage Road • Andover, MA. 01810 USA • Tel: (508) 470-2900 • Fax: (508) 475-6715
or Europe Carl-von-Linde Strasse 15 D-85748 Garching-Hochbruck, Germany • Tel: +49-89-329-2763 • Fax: +49-89-329-2767
Vicor Asia-Pacific 10F, No. 7, Ho Ping E. Road, Sec. 3, Taipei, Taiwan • Tel: 886-2-708-8020 • Fax: 886-2-755-5578

VICOR

CIRCLE NO. 136



500kHz-10MHz
14-bit Sampling A/D's

Secure your design's future ... Today!

Take control of your next design with a 14-bit A/D from DATEL. Each device is the proven performance, power, size and price leader in its class. Ideal for imaging, communications and radar/sonar applications, these versatile A/D's operate in commercial, industrial or military environments.

Secure your design's future today by selecting a sampling A/D that's ahead of its time.

- **Lowest prices**
- **Smallest packages**
- **Lowest power consumptions**
- **Low noise and distortion**
- **Ideal for demanding time or frequency-domain applications**
- **No missing codes over temperature**
- **MIL-STD-883 screening optional**

Model	Resolution (Bits)	Sampling Rate (MHz)	DNL (LSB)	No Missing Codes*	SNR (dB)	THD (-dB)	Power (Watts)	Package	MIL-STD-883 Screening Optional	Price OEM (USA)
ADS-926	14	0.5	±0.5	Yes	80	87	1.6	24-Pin DDIP	Yes	$205
ADS-927	14	1	±0.5	Yes	78	80	1.7	24-Pin DDIP	Yes	$237
ADS-929	14	2	±0.5	Yes	77	78	1.8	24-Pin DDIP	Yes	$271
ADS-944	14	5	±0.5	Yes	76	77	2.95	32-Pin TDIP	Yes	$479
ADS-945	14	10	±0.5	Yes	75	78	4.2	Custom DIP	No	$831

* 0 to +70°C or –55 to +125°C

DATEL, Inc., 11 Cabot Boulevard, Mansfield, MA 02048 Tel: (508) 339-3000
FAX: (508) 339-6356. For immediate assistance 800-233-2765.

DATEL
INNOVATION and EXCELLENCE

DATEL®

Panel Meter Mart

½ Digit, 0.56" LED Digital anel Voltmeters, DMS-30PC

$35/100s

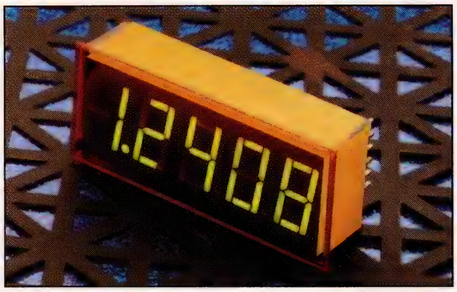
Miniature size: 2.17" x 0.93" x 0.56"
Fully encapsulated, 12-pin DIP package
7 LED colors, standard or high intensities
3 differential input voltage ranges
Single +5V supply
Numerous application boards available
el: 508-339-3000 • **1-800-233-2765**
ax 508-339-6356
TEL ▶ **CIRCLE 203**

Rugged, Low-Cost, LCD Digital Voltmeters, DMS-30LCD

$35/100s

- Miniature size: 2.17" x 0.93" x 0.43"
- Large (0.40") LCD display
- Backlit models optional
- Fully encapsulated, 12-pin DIP package
- 3 differential input voltage ranges
- Single +5V or +9V supply

Tel: 508-339-3000 • **1-800-233-2765**
Fax 508-339-6356
DATEL ▶ **CIRCLE 204**



4½ Digit, 0.52" LED Digital Voltmeters, DMS-40PC

$63/100s

- Miniature size: 2.17" x 0.93" x 0.56"
- Optional red, green or yellow LED colors
- Fully encapsulated, 12-pin DIP package
- 3 differential input voltage ranges
- Single +5V supply
- Hold and test functions

Tel: 508-339-3000 • **1-800-233-2765**
Fax 508-339-6356
DATEL ▶ **CIRCLE 205**

½ Digit, 0.40" LCD igital Voltmeters, DMS-40LCD

$63/100s

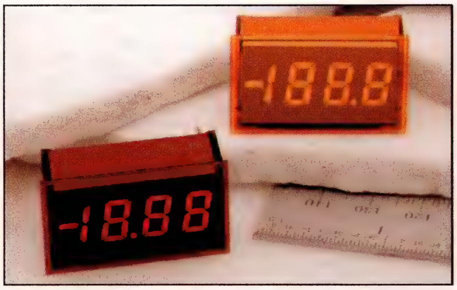
Miniature size: 2.17" x 0.93" x 0.43"
Backlit models optional
Single +5V or +9V supply (2.5mA)
Fully encapsulated, 12-pin DIP package
3 differential dual-input voltage ranges
Low-battery annunciator
el: 508-339-3000 • **1-800-233-2765**
ax 508-339-6356
ATEL ▶ **CIRCLE 206**

Plug-in/Panel Mount AC Line Monitor, DMS-20PC-1-LM

$40/100s

A 3½ digit, component-style voltmeter capable of direct wall outlet operation. UL recognition and choice of plug-in terminals (flat U.S., round Europe and screw-in lugs for panel mount). Operates from 85 to 264Vac (47-63Hz) and displays RMS voltage directly.

Tel: 508-339-3000 • **1-800-233-2765**
Fax 508-339-6356
DATEL ▶ **CIRCLE 207**



Subminiature, 0.37" LED Digital Voltmeters, DMS-20PC

$26/100s

Our smallest (1.38" x 0.88") component-style DPM is a fully functional, 3½ digit, precision measurement module available in 5 LED colors and 4 input voltage ranges. It's low cost, modular size and large (0.37" height) LED display make it ideal for OEM's and end-users.

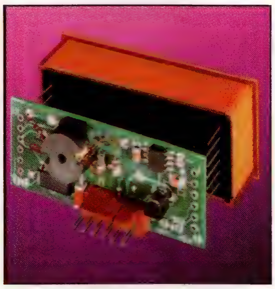
Tel: 508-339-3000 • **1-800-233-2765**
Fax 508-339-6356
DATEL ▶ **CIRCLE 208**

-20mA Loop Powered ½ Digit LCD Display

$62/100s

he DMS-30LCD-4/20S is unquestionably the asiest to use, most versatile product of it's type. pan, zero offset, and decimal point selections re all made on an 8 position DIP switch (no umpers!). Connections to the loop are via reliable, screw type terminal block.

el: 508-339-3000 • **1-800-233-2765**
ax 508-339-6356
ATEL ▶ **CIRCLE 209**



Application Boards for DMS-30LED and LCD Meters

- Install directly on DMS-30 Series meters
- RMS-to-dc conversion
- J and K-type thermocouple interface
- 4-to-20mA process monitoring
- Solid State temperature probe interface
- Isolated (750V) +5V primary power

Tel: 508-339-3000 • **1-800-233-2765**
Fax 508-339-6356
DATEL ▶ **CIRCLE 210**

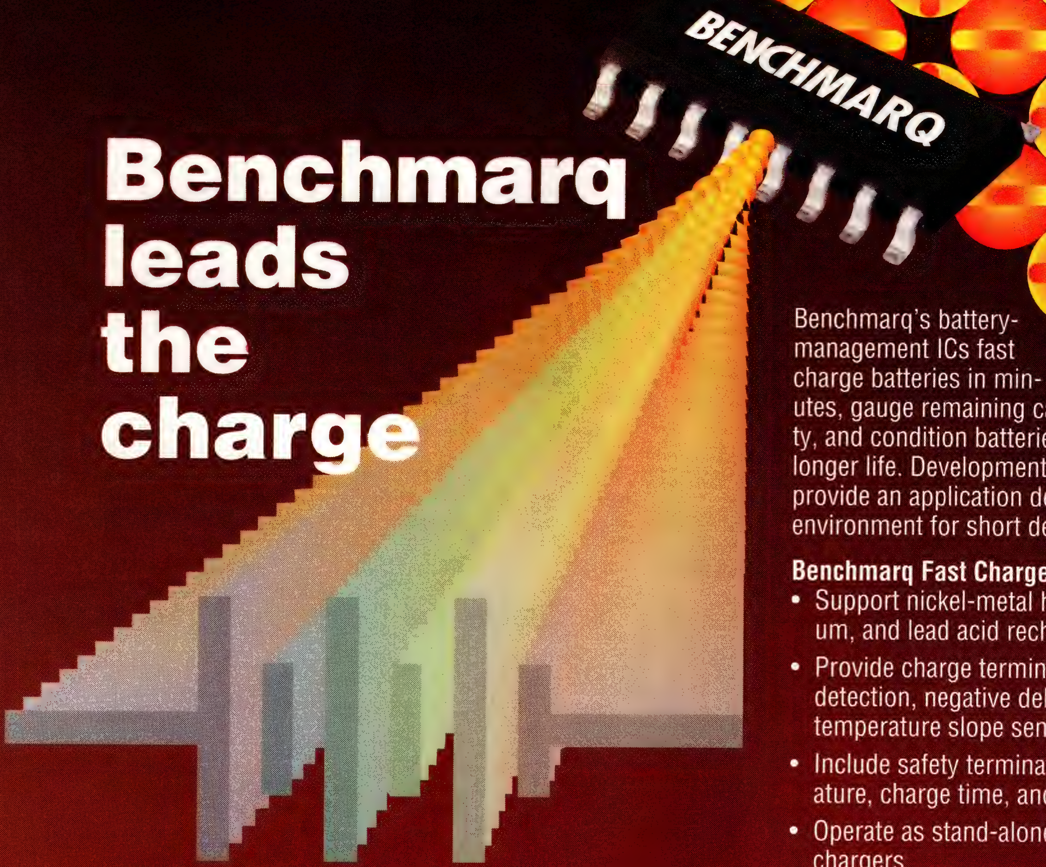
50 New Products from DATEL

New, 64-page, full-color catalog. Data acquisition and conversion components (to 16 bits and 125 MHz), modular DC/DC converters (to 50 Watts), 3½ and 4½ digit DPM's (LED/LCD), and I/O boards for PC/AT, EISA and VME (12-14 bits to 10Mhz). Custom products and EMI/EMC capabilities.

Tel: 508-339-3000 • **1-800-233-2765**
Fax 508-339-6356
DATEL ▶ **CIRCLE 211**

DATEL, Inc., 11 Cabot Boulevard, Mansfield, MA 02048-1194 Tel: (508) 339-3000 Fax: (508) 339-6356 • For immediate assistance: **1-800-233-2765**

Benchmarq leads the charge



Benchmarq's battery-management ICs fast charge batteries in minutes, gauge remaining capacity, and condition batteries for longer life. Development systems provide an application development environment for short design-in cycles.

Benchmarq Fast Charge ICs:

- Support nickel-metal hydride, nickel cadmium, and lead acid rechargeable batteries
- Provide charge termination based on peak voltage detection, negative delta voltage detection, and temperature slope sensing
- Include safety terminations on maximum temperature, charge time, and battery voltage
- Operate as stand-alone or system-integrated chargers

Benchmarq Gas Gauge ICs:

- Measure available charge in nickel-metal hydride and nickel cadmium batteries
- Integrate temperature sensor, self-discharge compensation, and high-resolution A-to-D for current measurement on a single chip
- Provide a cost- and space-effective means of designing a smart battery pack
- Display capacity via single-wire serial port or direct drive of LEDs

For information about these and other battery management solutions, call Benchmarq at 1-800-966-0011.

Battery Management Selection Guide

Part No.	Description	Battery Technology	Pins/ Package
bq2002	Low-Cost Fast Charge IC With PVD	NiMH, NiCd	8/0.300" DIP, 0.150" SOIC
bq2003	Fast Charge IC With $-\Delta V$ and $\Delta T/\Delta t$	NiMH, NiCd, Lead Acid	16/0.300" DIP, 0.300" SOIC
bq2004	Fast Charge IC With PVD and $\Delta T/\Delta t$	NiMH, NiCd	16/0.300" DIP, 0.150" SOIC
bq2005	Dual-Battery Fast Charge IC With $-\Delta V$ and $\Delta T/\Delta t$	NiMH, NiCd	20/0.300" DIP, 0.300" SOIC
bq2007*	Fast Charge IC With Enhanced Display	NiMH, NiCd	24/0.300" DIP, 0.300" SOIC
bq2010	Gas Gauge IC	NiMH, NiCd	16/0.300" DIP, 0.150" SOIC
bq2110	bq2010 Module	NiMH, NiCd	Hybrid
bq2011	Gas Gauge IC for Power Tools	NiCd	16/0.300" DIP, 0.150" SOIC
bq2111	bq2011 Module	NiCd	Hybrid
bq2012	Gas Gauge IC With Charge Control	NiMH, NiCd	16/0.300" DIP, 0.150" SOIC
bq2112	bq2012 Module	NiMH, NiCd	Hybrid
bq2014*	Gas Gauge IC With External PVD and $\Delta T/\Delta t$ Charge Control	NiMH, NiCd	16/0.300" DIP, 0.150" SOIC
bq2114*	bq2014 Module	NiMH, NiCd	Hybrid

*Available 4Q94

Fast charge development boards provide gated, linear, switching, and off-line current regulation.

Gas gauge evaluation boards provide flexible development environment, including PC/AT communications software.

BENCHMARQ Microelectronics, Inc.
2611 Westgrove Dr. Suite 109
Carrollton, TX 75006 U.S.A.
800-966-0011 or 214-407-0011
Fax: 214-407-9845

BENCHMARQ

A Battery of Great Solutions

CIRCLE NO. 4

Maximize dynamic range in CCD-based imaging systems

STEVE RUSCAK, ANALOG DEVICES INC

The promises of multimedia and the "paperless office" have fueled explosive growth in the electronic-imaging industry. The CCD sensor at the heart of imaging systems needs careful signal conditioning to achieve maximum performance.

The center of virtually any electronic-imaging system is its light sensor, the ubiquitous charge-coupled device (CCD). Realizing the sensor's full dynamic range while converting its signal to the digital domain, however, requires signal conditioning. Although many engineers are familiar with conditioning circuits, optimizing them for an imaging signal requires an understanding of how each conditioning step affects the CCD output signal.

Fig 1 shows a generalized block diagram for the analog front end of a CCD-based imaging system. In the first stage, the CCD output feeds into a difference amplifier. The next stage is a noise-reduction circuit specific to CCD-based signals: the correlated double sampler (CDS). Following the CDS, a variable-gain stage compensates for variable-input light levels and any other factors that may affect the signal gain needed.

The conditioned signal is then ready for conversion to the digital domain. The imaging system's pixel rates and dynamic-range requirements dictate the A/D converter's speed and resolution. Systems with low to moderate dynamic-range requirements generally use 8- or 10-bit-resolution converters. High-end systems require A/D converters with 10- to 16-bit resolution.

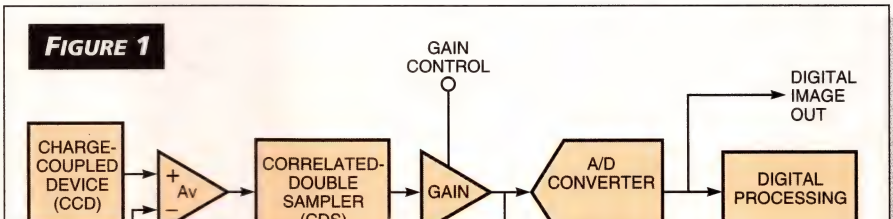
Due to the variability of the CCD output signal and additional offsets accumulated in the signal chain, all imaging systems require a way of adjusting signal offset. A combination of analog and digital processing handles this problem most effectively. A low-bandwidth servo loop, commonly known as dc restoration, adjusts coarse dc offset in the analog domain. An entirely digital approach—or one using a D/A converter to feed back an analog correction voltage—performs fine dc offset adjustment.

Begin with the sensor

Understanding the special needs of image signal conditioning begins with the CCD sensor. The CCD sensor is an array of individual photo-sensitive elements that converts light from an image into electrical charge. These elements can pass their charge, in bucket-brigade fashion, to an adjacent element in a scan line and on to the output stage. The CCD's output stage then converts this charge into a voltage, producing a serial stream of pixels. Most of the array's elements are exposed to light, but some elements are covered by a light-impermeable coating at one or both ends of each scan line. These elements form black pixels, which conditioning circuitry uses to adjust signal offset.

Fig 2 shows a typical output signal from a CCD sensor; the signal's five important attributes are

FIGURE 1



Except for the correlated double sampler unique to CCD-based systems, an imaging system's analog front end uses familiar circuit elements. The CCD's stepped-voltage signal, however, makes settling time and dynamic range more important parameters than the more familiar bandwidth and distortion.

- The zero reference or "reset" level
- The video level
- Reset feedthrough
- Pixel rate
- Amplitude.

The reset level, reset feedthrough, and the video portion of the signal constitute a single pixel. Video levels closer to the zero reference represent darker images; brighter images result in an increasing difference between the reset and video levels.

Typical pixel rates for CCDs in image scanners range from 1M to 3M pixels/sec. The CCDs in digital cameras operate at faster rates, ranging from 13.5M to greater than 20M pixels/sec. The amplitude of the output signal is proportional to the amount of light present on the sensor. Nominal full-scale output signals range from 0.5 to 1.5V.

The CCD signal is inherently unipolar and fundamentally comprises a series of stepped dc signals. This stepped nature places a particular set of constraints on the analog signal-conditioning circuitry. Rather than considering typical dynamic specifications such as harmonic distortion and aperture jitter, designers must be more concerned with system issues like dynamic range, settling time, and noise.

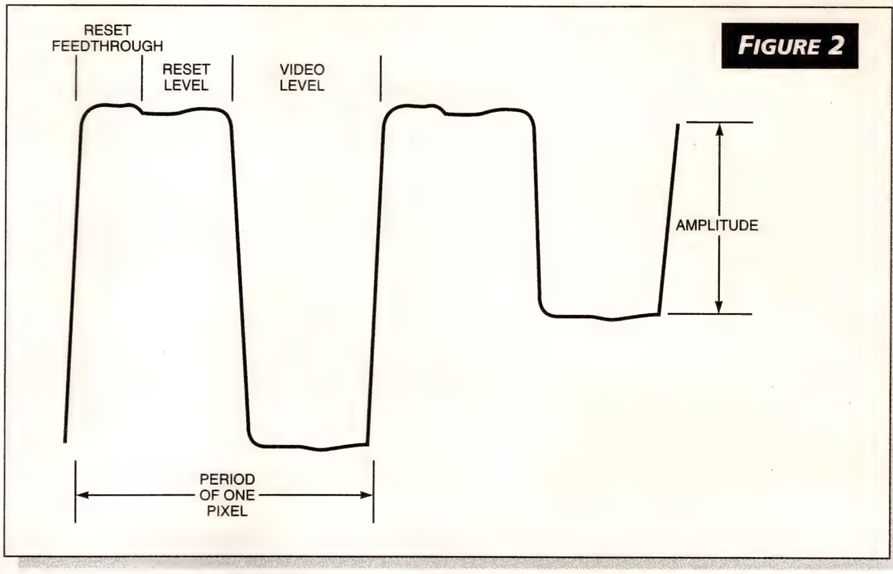
CDS reduces noise

Imaging systems use a circuit called a correlated double sampler (CDS) to reduce the effective noise on the CCD output signal's dynamic range. The circuit's name comes from its double sampling of the input signal—once during the signal's reset portion and once during the video portion. The CDS reduces 1/f noise and kT/C noise generated at the CCD output pin. Additionally, the CDS reduces noise that correlates between the signal's reset and video portions.

In its most conceptually simplistic form, two S/H amplifiers (SHAs) and a difference amplifier compose a correlated double sampler. **Fig 3a** shows a representative design. The incoming signal drives the input stages of both IC_1 and IC_2. (IC_1 and IC_2 are AD783, high-speed SHAs capable of acquiring a 2V step input in 250 nsec; with regard to noise and accuracy, this SHA type suits circuits that require 10- and 12-bit performance.)

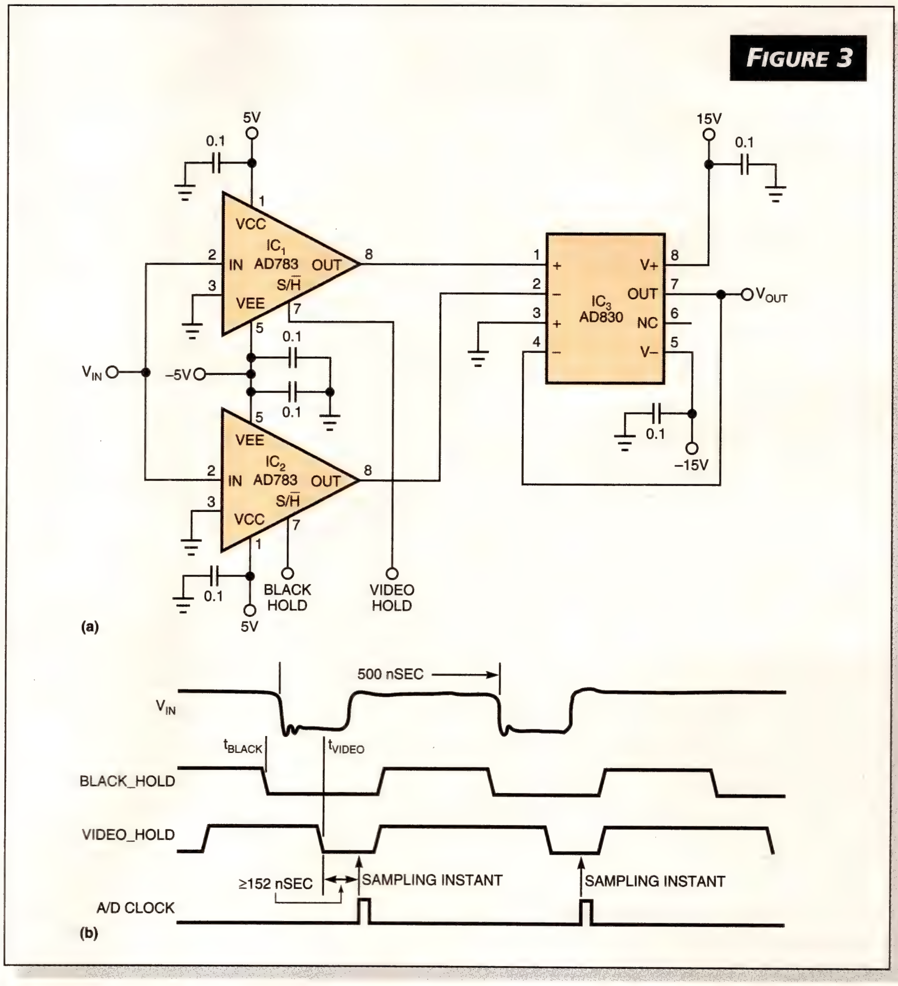
The SHA's output signals connect to the positive and negative inputs of an

FIGURE 2



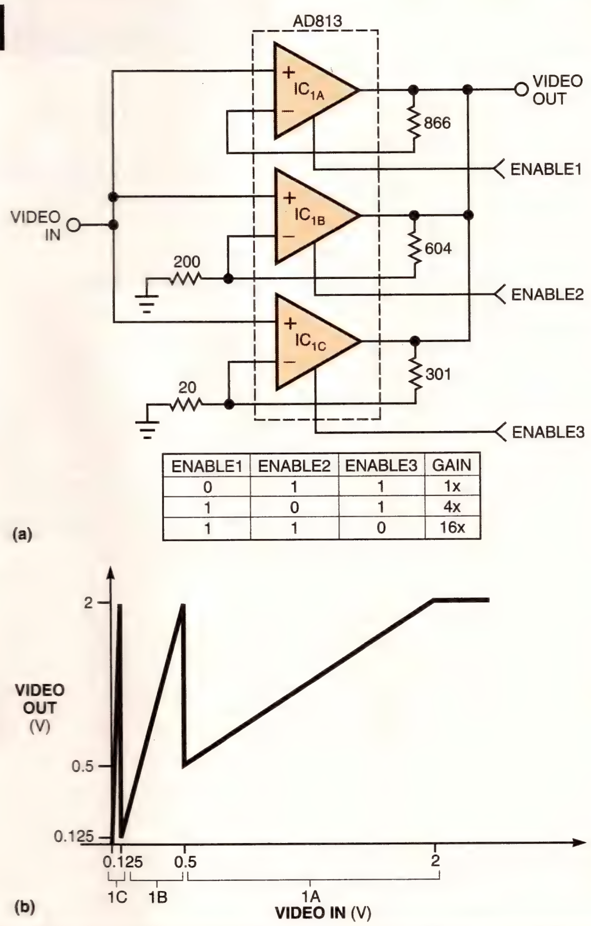
The charge coupled display's (CCD) output signal is essentially a series of voltage steps. The signal's major features include reset and video levels, amplitude, and pixel frequency.

FIGURE 3



The correlated double sampler reduces noise in CCD-based signals by comparing the reset and video levels. The circuit in (a) uses two S/H amplifiers (SHAs). Timing pulses (b) ensure that the signals have settled before being held or digitized.

FIGURE 4



ENABLE1	ENABLE2	ENABLE3	GAIN
0	1	1	1x
1	0	1	4x
1	1	0	16x

A programmable gain circuit (a) using current-feedback amplifiers keeps the input signal matched to the A/D converter's input range (b). Using the amplifiers' enable control eliminates the need for external switches.

integrated difference amplifier, IC_3. The equation describing the circuit's function is

$$V_{OUT}=V_{IN}(t_{VIDEO})-V_{IN}(t_{BLACK}),$$

where V_{OUT} and V_{IN} are in volts. Time values t_{VIDEO} and t_{BLACK} indicate the sampling instances corresponding to the CCD signal's video and reset levels, respectively.

The timing diagram in **Fig 3b** helps clarify the circuit's operation. Following the reset feedthrough and some additional settling, the falling edge of BLACK_HOLD drives the $S/\overline{H}$ pin of IC_2. This falling edge places IC_2 in hold mode. A settled sample value of the reset level becomes available at IC_2's output pin 150 nsec later. After the video portion of the pixel has settled to the required accuracy, the falling edge of VIDEO_HOLD places IC_1 in hold mode. The video signal at IC_1's output pin settles to 12-bit accuracy 150 nsec later.

The held output signals from IC_1 and IC_2 drive the positive and negative input pins, respectively, of IC_3. The output signal from IC_3 is the difference between the held outputs of IC_1 and IC_2. The combined settling time of both IC_1 and IC_3 determines when the entire circuit's output becomes valid. A root-sum-square combination of the two settling times,

$$t_{TOTSTL}=(t_{IC1}^{2}+t_{IC3}^{2})^{0.5},$$

provides a first-order approximation to the circuit's total settling time. Because IC_3's output signal settles in approximately 35 nsec, the SHA's 150-nsec settling time dictates a minimum total settling requirement of 152 nsec. Circuitry between the difference amplifier and the A/D converter may require additional settling time.

To maximize throughput with this particular CDS architecture, IC_1 returns to acquisition mode as soon as the A/D converter has sampled the settled signal. This immediate return is necessary because of the SHA's finite acquisition time. The timing diagram indicates the optimal sampling instant for the A/D converter.

Match signal with A/D input

The CDS's primary function is to reduce noise, thereby increasing the imaging system's effective dynamic range. Adjusting the sampled signal's magnitude to span as much of the A/D converter's input range as possible also increases the system's dynamic range. Many techniques are available to adjust signal magnitude. Analog multipliers and multiplying D/A converters are the most obvious gain elements.

Alternatively, you can use a simple, programmable gain amplifier (PGA) to achieve the range match. By using, in conjunction with the PGA, an A/D converter that has a dynamic range exceeding the overall system dynamic-range requirement, it becomes unnecessary to provide precision gain calibration in the analog signal chain. A digital multiplier performs the precision gain correction in the digital domain.

Digital multiplication, however, is an additional source of quantization noise. Applying a digital gain of 12 dB, for example, reduces the converted 10-bit signal's dynamic range by up to 2 bits. Yet multiplication up to 12 dB can still achieve the original system's dynamic-range requirement if the A/D converter has 12 dB of dynamic range overhead. For example, a system attempting to achieve 8 bits of dynamic range requires a 10-bit A/D converter.

Even though there are several well-known programmable gain circuits (see **Ref 2**), **Fig 4a** shows a novel and efficient PGA constructed with current-feedback op amps that have an output disable feature. Similar to a multiplying D/A converter, this PGA has the desirable characteristic of a digital control structure. The circuit is noninverting and provides three possible gain ranges: 1, 4, and 16×. (See the circuit's transfer function in **Fig 4b**.) This choice of ranges assumes that the imaging A/D converter in the signal chain has approximately two additional bits (~12 dB) of dynamic range than the overall system's requirement.

The **table** in **Fig 4a** shows the correspondence between a particular amplifier being active and its associated gain range. When ENABLE1 is low, follower-connected amplifier IC_{1A} is active. In a gain of 1×, if the digital multiplication would have to be greater than 12 dB, a reduction in dynamic range would result because of the limited number of bits in the A/D converter. Instead, signals with magnitudes between [1/4] and [1/16] the full-scale input range of the A/D converter turn on IC_{1B}, placing the PGA in a gain of 4×. Another gain range boundary at 16× handles signals between zero and one-sixteenth full scale. The circuit always attempts to produce signal magnitudes between 25 and 100% of the A/D converter's full-scale input span.

The circuit in **Fig 4** is unique in that it does not require an analog switch and uses current-feedback amplifiers. The use of current-feedback amplifiers such as the AD813 for a PGA has several advantages. Perhaps most important is the circuit's constant gain-bandwidth product. PGAs that use voltage-feedback op amps quickly run out of bandwidth at higher gain settings. Another advantage of this PGA circuit is that the output enable/disable feature switches in less than 180 nsec. This kind of switching speed is comparable to external switches without the concerns of switch nonidealities.

CCDs need offset correction

Virtually all gain correction schemes require an effective way of zeroing the system offset. A signal with p-p amplitude corresponding perfectly to the A/D converter's full-scale input span—but with an objectionable offset—produces a clipped signal at the digital output. Conversely, a system that has an improper offset can only provide signal gain by an amount equal to the full-scale input span of the A/D converter minus the magnitude of offset. In the first case with the clipped signal, the converted signal's dynamic range decreases sharply. In the second case, the maximum possible input is not being applied to the A/D-converter input and again reduces the dynamic range.

A combination of analog offset correction (known in imaging systems as dc restoration) and digital offset correction offers the optimal system. DC restoration nominally shifts the A/D-converter input signal so that the black signals correspond to negative full-scale voltage on the A/D converter. The digital offset correction precisely compensates both A/D-converter offset errors and any residual system errors from the analog front end.

ERROR SOURCES IN IMAGING SYSTEMS

CDS:
- Hold-mode offset
- Gain error
- Hold-mode settling
- Acquisition time

PGA:
- Offset
- Settling time
- Noise
- Gain bandwidth, especially at high gain ranges
- Gain linearity vs control voltage
- Limited resolution: How many gain ranges do you need?

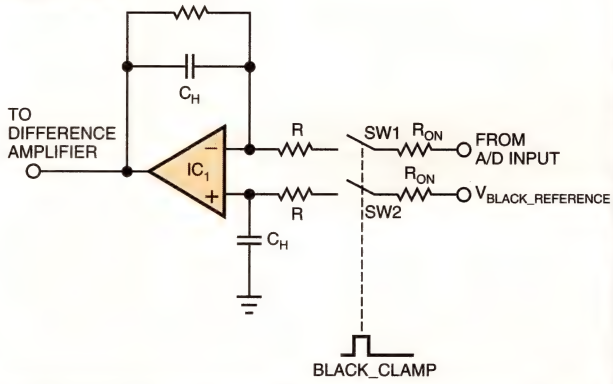
Difference amplifier:
- Common-mode rejection
- Settling time
- Offset

A/D converter:
- Resolution
- SNR vs reference span
- Sample clock duty cycle
- Settling time
- Reference bandwidth

Offset D/A converter:
- Resolution
- Settling time
- Adjustment resolution
- Offset sources

DC restore amplifier:
- Offset (from pedestal and amplifier)
- Hold-mode feedthrough
- Droop

FIGURE 5



A dc restoration circuit can correct most offset errors in the imaging system's front end. The circuit integrates the difference between a blank pixel and a zero reference and then feeds that signal back to level-shift the CCD signal.

CCD output signals typically have very large offsets, often as much as 5 to 12V. In high-speed video applications, ac-coupling and a "clamp" circuit level-shift this offset to a more convenient quiescent operating point. In low-speed, high-accuracy applications, dc-coupling and difference amplifiers subtract the offset. In both applications, a dc restore circuit measures any residual offset from the level-shifters just prior to the A/D converter input.

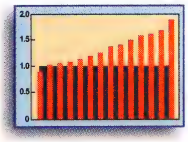
DC restore for coarse correction

Fig 5 shows a generalized schematic for a common dc restore circuit. The dc restore is simply a crude SHA. The circuit's architecture is closed-loop and is typically differential to reduce pedestal errors and V_{DROOP}. DC restore circuits usually have a long time constant and slow response time.

The circuit's behavior is straightforward. An appropriately timed sampling command, BLACK_CLAMP, switches on SW1 and SW2 during the light-shielded pixels in a scan line. Op-amp IC_1 integrates the difference between the signal level at the A/D converter input pin and the desired black level. SW1 and SW2 then open, causing the

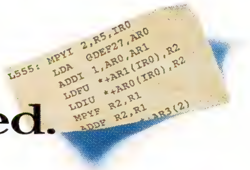
Fastest C compiler.

For Texas Instrument DSPs.



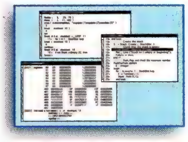
21% **faster code.**

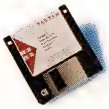
No assembly required.



```
L555: MPYI  2,R5,IR0
      LDA   @DEF27,AR0
      ADDI  1,AR0,AR1
      LDFU  *+AR1(IR0),R2
      LDIU  *+AR0(IR0),R2
      MPYF  R2,R1
      ADDF  R2,R1      *+AR3(2)
```

Powerful Windows™ debugger





Introducing Tartan C.

This is for real.

Also v2.0 of Tartan **C/C++ for DSPs.**

Real-time object-oriented programming.

Not convinced?

⇩

We'll **prove it.**

1•800•856•5255

ext. 200 for free information and benchmarks

TARTAN

Tartan, Inc. • 300 Oxford Drive • Monroeville, PA 15146 • Tel: 412.856.3600 • Fax: 412.856.3636 • Internet: info@tartan.com

Windows is a trademark of Microsoft Corp.

CIRCLE NO. 86

integrating action to stop. The op amp holds its output value while the switches are open.

The op amp's output signal feeds back to a difference amplifier at the beginning of the signal chain where the signal counters the dc offset error in the forward signal path. If the A/D converter's input signal is greater than the desired black level, the op amp's output signal ramps negatively. Conversely, when the A/D-converter input signal is less than the black level, the output signal ramps positively.

Selecting component values for the design requires use of only a few simple equations to set the circuit's acquisition speed and output-hold-signal V_{DROOP} rate. Remember that the function of the circuit is coarse offset adjustment; first-order approximations are sufficient. For instance, the circuit's time constant is all that's needed to describe the circuit's settling time.

Set component values

When large differences exist between the A/D converter's input signal and the reference black level, the op amp supplies slew current, quickly ramping its output signal until its input signals are within their linear settling range. From that point, the circuit's time constant

$$\tau=[(R_{ON}+R_{IN})\times C_H]/2$$

dictates the time required or the output signal to settle a desired error band. A single-pole, linear settling model gives a first-order approximation of how quickly the output gets to the desired voltage.

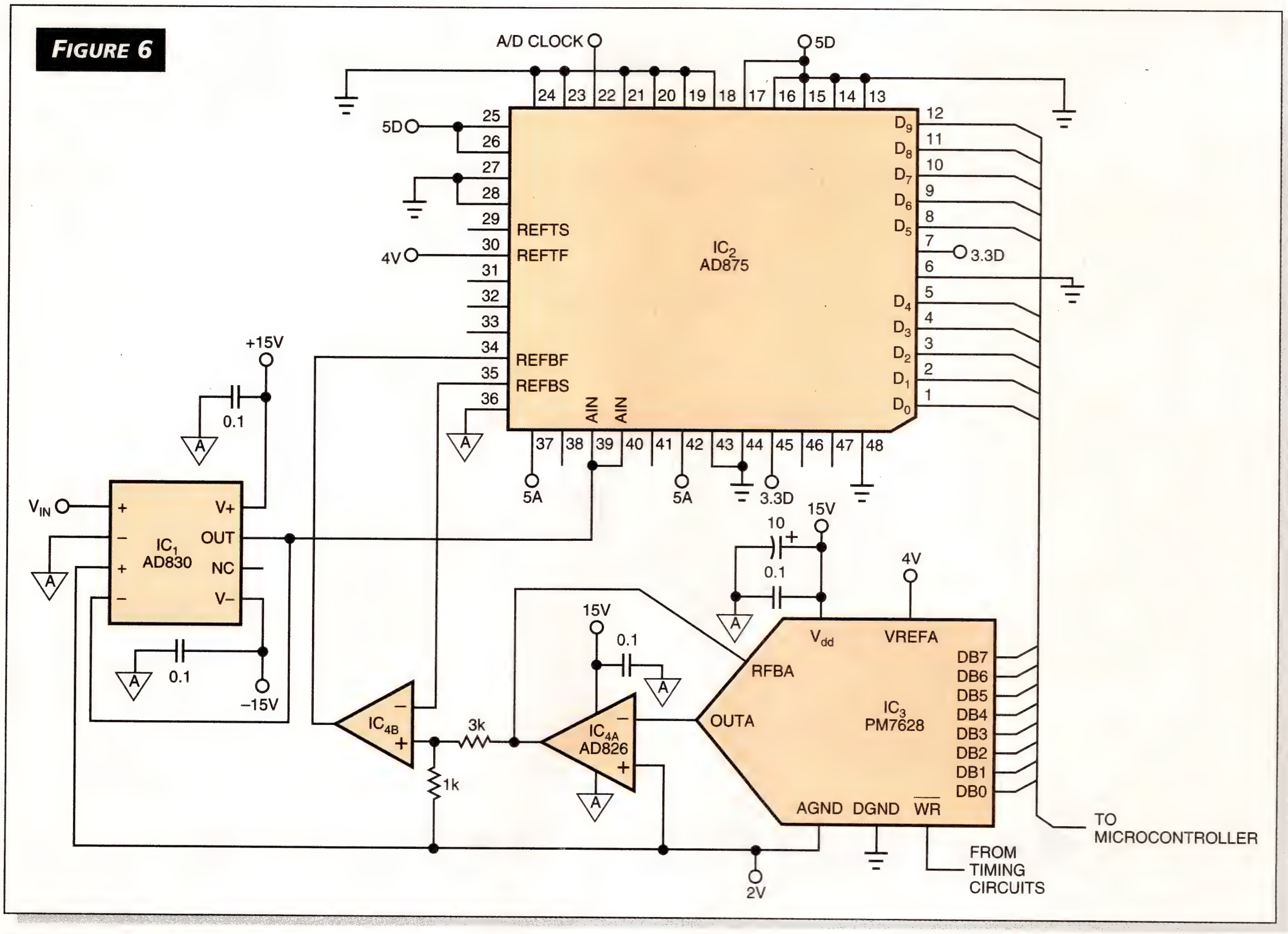
However, because the output can only change when the switches are closed, it is also necessary to take into account the finite charge period. For example, if the switches were always closed, a step change of the input voltage would require 7.6 time constants for the output voltage to settle to 10-bit accuracy. Because the switches close only periodically, the number of samples (N) required to achieve a particular level of accuracy become

$$N=(a\times\tau)/\Delta t_{SAMPLE}, \qquad \textbf{(Eq 1)}$$

where a=the number of time constants required for a desired level of accuracy, and Δt_{SAMPLE}=the switch-on time in sec. System-timing constraints set the switch-on time, and the CCD sensor has a set number of light-shielded pixels, setting an upper limit for N. Given those system constraints and the desired settling accuracy, use **Eq 1** to calculate the circuit time constant required.

When the circuit is in hold mode, the size of the hold capacitor (C_H) and various leakage sources determine its

FIGURE 6



A digital offset-control scheme corrects for small offset errors. The digitized value of reference black pixels (by definition, zero) contains an offset error term that feeds a D/A converter. The converter produces a correction voltage to subtract out the error.

LAST CALL!

DESIGN SUPERCON'95

The Conference about Putting Technology to Work

"Design Expertise for Designers"

February 28 to March 2, 1995 **Santa Clara, CA**

Call for Papers

Co-developed by *EDN* and Hewlett-Packard Co

HIGH-PERFORMANCE SYSTEM DESIGN CONFERENCE

Authors are invited to submit abstracts, biographies, and/or completed papers on recent advances, practical design techniques, and case studies in the design of advanced digital systems. Areas of interest include, but are not limited to:

☛HIGH-PERFORMANCE COMPUTING ARCHITECTURES

- Multiprocessing
- Reconfigurable hardware
- 100+MHz microprocessors
- ESDA (practical aspects)
- Packaging effects on architecture design
- Memory/cache design

☛ HIGH-SPEED DATA MOVEMENT

- High-performance bus design (PCI bus, EISA, VL)
- Using high-speed serial links
- I/O-system design
- Driver/interconnect effects on high-speed data movement
- Timing analysis and verification
- Optimizing mass-storage communication

☛REAL-WORLD EFFECTS ON DIGITAL SYSTEMS

- Signal integrity
- Practical pc-board layout techniques
- Electromagnetic interference (EMI)
- Clock distribution
- High-speed packaging effects
- Metastability

☛HIGH-PERFORMANCE EMBEDDED DESIGN

- DSP supplanting traditional CPU
- Graphic-system design
- Image processing
- Debugging high-performance embedded systems
- Embedded hardware/software integration
- CASE for embedded system design

Note: Existing papers in the areas of interest should be sent along with the abstracts/biographies.

SUBMISSION INSTRUCTIONS

Send six copies of your abstract, biography, and double-spaced, double-sided existing papers to:

Markus Levy
EDN Magazine
1936 Sheffield Drive
El Dorado Hills, CA 95762
EMAIL: EDNLEVY@MCIMAIL.COM
Phone: (916) 939-1642
Fax: (916) 939-1650
(Please do not submit papers by fax)

EDN®

hp HEWLETT PACKARD

output V_{DROOP}. Pertinent equations are

$$I_{LEAKAGE}=I_{OFFSET}+\Delta I_{SWLEAK} \quad \text{(Eq 2)}$$

$$V_{DROOP}=[(I_{LEAKAGE})/(C_H/2)]\times\Delta t_{LINE} \quad \text{(Eq 3)},$$

where $I_{LEAKAGE}$=the total of the differential leakage sources (A),

I_{OFFSET}=the op-amp offset current (A),

ΔI_{SWLEAK}=the difference in leakage currents of SW1 and SW2 (A),

V_{DROOP}=the change in SHA output voltage during one scan line, and

Δt_{LINE}=the scan line period (sec).

When the circuit is in hold mode, you do not want the output to change more than one least significant bit (LSB) during a scan line period. From **Eq 2** and **3**, calculate the hold capacitor's minimum requisite size. Given the desired value of τ from **Eq 1** and the fact that R_{ON} is determined by the particular switch used for SW1 and SW2, R_{IN} is the only component left to calculate.

Control for fine adjustments

This dc restore circuit provides the imaging system's coarse offset adjustment; a digital process provides fine offset control. The digital offset algorithm begins by scanning a "zero" or black reference signal, which corresponds to the A/D converter's negative full scale. The converter digitizes this zero signal. On the basis of a digital correction signal derived from that forward-converted data, a D/A converter creates an analog correction signal to feed back into the signal chain. A convenient place to apply the correction voltage is the reference of the A/D converter—if the converter has an adjustable reference.

Fig 6 shows a digital offset-correction circuit that utilizes the A/D converter's output data without additional processing. A 2V reference signal drives pin 3 of difference-amplifier IC_1, an AD830. The difference amplifier level-shifts the conditioned CCD input signal's range of 0 to 2V to the A/D converter's nominal 2 to 4V input range. The AD875 A/D converter, IC_2, is a single-supply, 15M-sample/sec, 10-bit CMOS A/D converter. The voltage applied across reference-terminals REFTF and REFBF determine the converter's input span.

Before IC_2 converts the black pixel "zero" signal, a µC presets digital code 00H into IC_3, an 8-bit D/A converter. The resultant output from IC_{4B}, nominally 2V, drives REFBF. Preset completed, IC_2 then converts the "zero" signal, and a timing pulse latches the converter's digital output value directly into IC_3.

Because the input signal is, by definition, zero, any nonzero digital value represents the circuit's accumulated analog front-end offset in addition to the converter's inherent offset. The D/A converter, in conjunction with current-to-voltage converter IC_{4A}, a resistive divide-by-four, and buffer IC_{4B}, responds to a nonzero sample by increasing the voltage at the REFBF an amount equal to the offset. Configuring IC_{4B} in a force-sense connection minimizes offsets IR drops generate in the internal resistor ladder of the A/D converter.

One of the most important aspects of digital correction-loop design is determining the required correction resolution. The reference span selected for IC_3 scales current at the D/A-converter pin such that IC_3's LSB represents four times the voltage for IC_2's LSB. Reducing this reference span reduces the LSB's size but also reduces IC_3's relative accuracy. Instead, the resistive divider reduces IC_{4A}'s 2 to 4V output span to a 0.5V correction range. By using the resistive divide-by-four, this circuit increases the correction signal's effective resolution to the 10-bit level.

Note that the black reference signal at IC_2 initially must be greater than the converter's negative full-scale reference voltage. If IC_2's input offset were below negative full-scale, the digital calibration loop would interpret the signal as a "no offset" condition. The result would be an incorrect correction voltage. Applying a skewed voltage to the $V_{BLACK\_REFERENCE}$ input (SW2) of the dc restore circuit (**Fig 5**) forces the needed positive initial offset into the forward signal path. This implies that the dc restore circuit must be able to servo the forward signal path's offset in the range $2V \leq V_{IN} < 2.5V$.

Consider other error sources

Although the CCD's offset voltage is the largest error source in an imaging system's front end, it is not the only important one. The **box**, "Error sources in imaging systems," lists other significant error sources for each building block in the conditioning circuit. This list offers a good starting point when analyzing an imaging signal chain. Even though individual errors may be relatively benign, integrating the blocks together exposes a number of interactions.

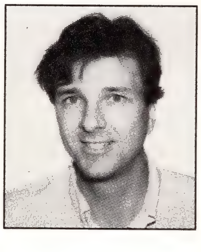
As with offset, system errors become more important when PGAs are in use because different gain settings result in different errors. Although some of the error sources in the **box** may be more critical than others, it is necessary to evaluate even the less important specifications to maximize an imaging system's dynamic range. Keep in mind, also, that settling time is critical for every component in the forward signal path due to the stepped nature of the CCD signal. EDN

References

1. Kansy, RJ, "Response of a Correlated Double Sampling Circuit to 1/f Noise," *IEEE Journal of Solid-State Circuits*, Volume SC-15, No. 3, June 1980.

2. Buxton, Joe, "Programmable Gain Amplifiers," *Analog Devices System Applications Guide*, pgs 3-1 to 3-9.

Author's biography

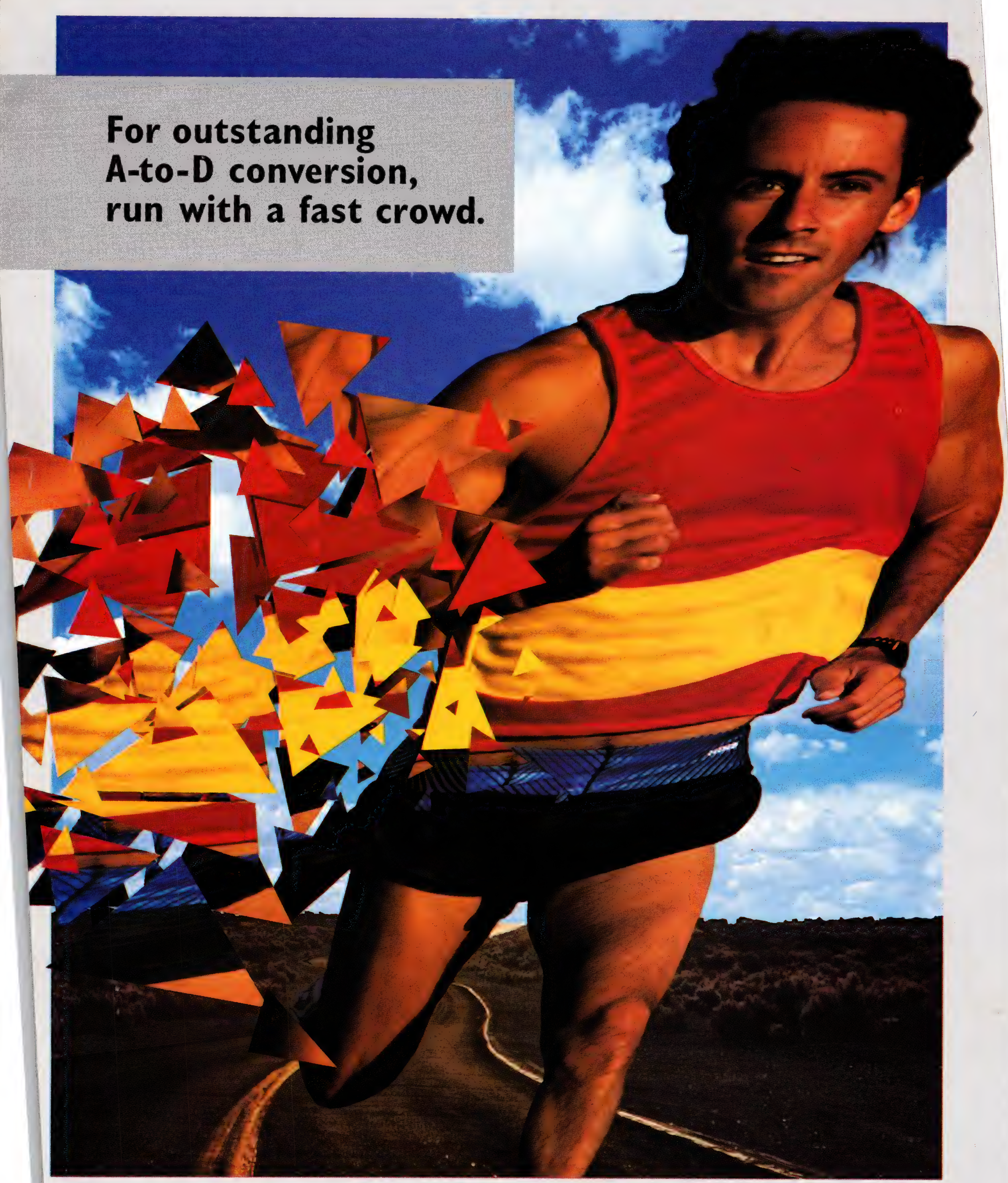


Steve Ruscak is an applications engineer for Analog Devices Inc, where he has worked for five years supporting high-speed converter products. He specializes in imaging and video processing systems and is a member of SMPTE. Steve obtained his BSEE from Northeastern University in Boston; in his spare time, he enjoys music and cycling.

VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

High Interest	Medium Interest	Low Interest
592	593	594



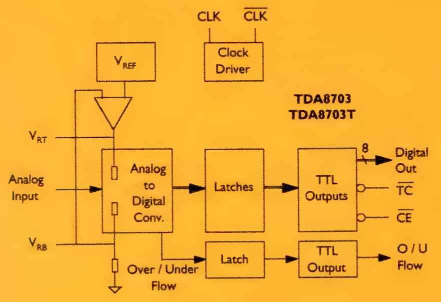
Philips
Semiconductors

PHILIPS

Run with Philips, the world's broadest family

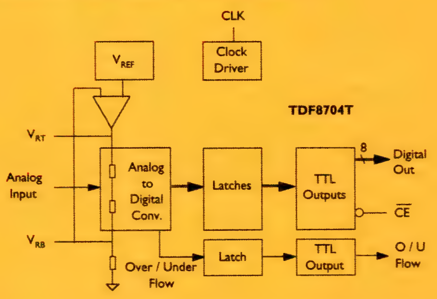
Part Type	I/O	Conversion Rate Min. (MSPS)	Resolution (Bits)	Effective Bits (@ MHz)	Power Diss. (mW)	Features
Video Signal Conditioning and Digitizing ICs						
TDA8708A TDA8708B	TTL	30	8	7.5@4.43	365	3:1 Mux, AGC, Clamp
TDA8709A	TTL	30	8	7.5@4.43	380	3:1 Mux, VGA, Clamp
TDA8758	TTL	30	8	7.2@4.43	485	Mux, AGC, Dual ADC, 16 Bit YC
TDA8755	TTL	20	8	7.1@4.43	550	Clamps, Dual ADC, YUV 4:1:1
TDA8706	TTL	20	6	5.7@4.43	300	3 Clamps, 3:1 Mux
High-Speed A-to-D Converters						
TDA8718	ECL	600	8	7.5@4.43	990	Low Cin 0 & U Flow
TDA8716	ECL	120	8	7.7@4.43	780	Low Cin 0/U Flow
TDA8714/7 TDA8714/6 TDA8714/4	TTL	75 60 40	8	7.7@4.43	340	0/U Flow
TDF8704/5 TDF8704/4 TDF8704/2	TTL	50 40 20	8	7.5@4.43	380	-40/+85°C Temp, Internal Ref.
TDA8760/5 TDA8760/4 TDA8760/2	TTL	50 40 20	10	8.8@4.43	850	S/H, 0/U Flow
TDA8703	TTL	40	8	7.1@4.43	290	Internal Ref., 0/U Flow

TDA8703 8 Bit High Speed A/D



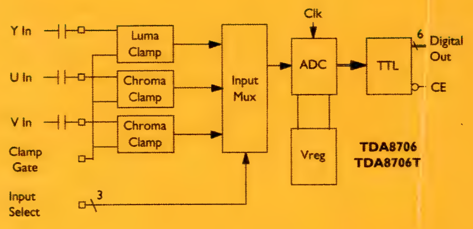
- 8 bit A/D
- 40 MHz minimum sample rate
- Internal voltage reference
- 7.1 effective bits @ 4.43 MHz input
- 14 pF input capacitance
- Binary or two's complement output
- TTL I/0 and 3 state outputs
- Overflow/underflow 3 state output
- +5 V supply. 290 mW power dissipation
- 24 pin DIP or SO

TDF8704 High Speed & Temperature A/D



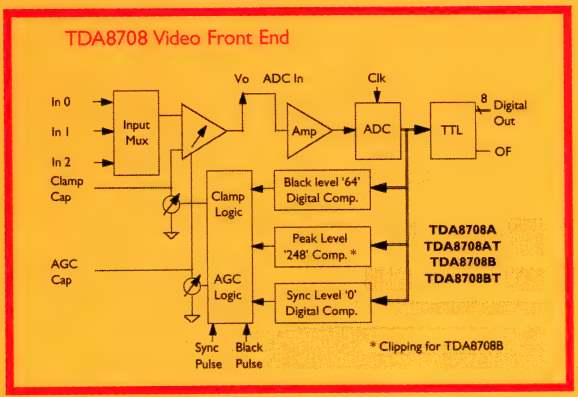
- 8 bit A/D
- 50 MHz minimum sample rate
- -40°C to +85°C operating temperature
- Internal voltage reference
- 7.5 effective bits @ 4.43 MHz input
- 14 pF input capacitance
- Binary output
- TTL I/O and 3 state outputs
- Overflow/underflow 3 state output
- +5V supply. 380 mW power dissipation
- 24 pin SO

TDA8706 6 Bit A/D with Mux



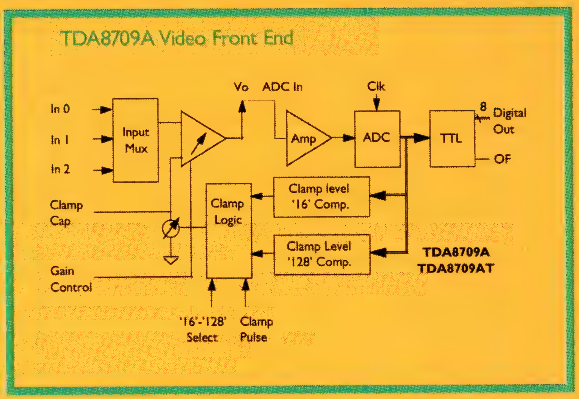
- 6 bit A/D
- YUV digitizing
- Luminance '0' clamp
- Two chrominance '128' clamps
- 3:1 input Video MUX
- 20 MHz min. A/D sample rate
- 5.7 effective bits @ 4.43 MHz input
- Internal voltage reference
- +5 V supply. 300 mW power dissipation
- 20 pin DIP or SO

f feature rich, high-speed A-to-D converters.


TDA8708 Video Front End

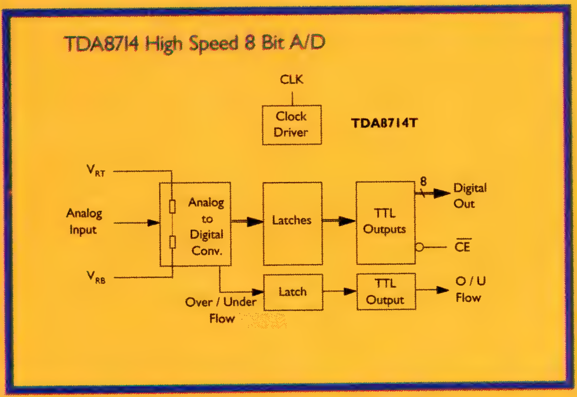
* Clipping for TDA8708B

- 8 bit folding/interpolating A/D
- Front-end A/D
  - PAL, NTSC, SECAM, Y
- 3 input video MUX
- Black level clamp
- Sync amplitude AGC
- 30 MHz minimum sample rate
- 1 pF input capacitance
- 7.5 effective bits @ 4.43 MHz
- +5 V supply. 365 mW power dissipation
- 28 pin DIP or SO

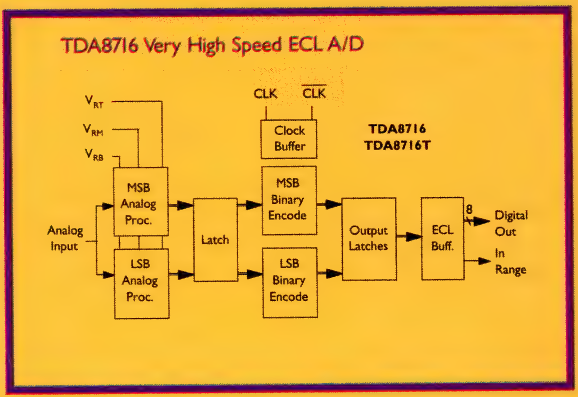

TDA8709A Video Front End

- 8 bit folding/interpolating A/D
- Front-end A/D
  - PAL, NTSC, SECAM, Y-C
- 3 input Video MUX
- Back porch clamp '16' or '128'
- Variable gain amplifier
- 30 MHz minimum sample rate
- 1 pF input capacitance
- 7.5 effective bits @ 4.43 MHz
- +5 V supply. 380 mW power dissipation
- 28 pin DIP or SO

With speeds up to 600 million samples per second, high integration and affordable pricing, our large and ever-growing line of A-to-D converters is a real crowd pleaser among design engineers. So put our extensive A-to-D video experience to work for you. Call now for more information on these eleven speedy A-to-D devices: **1-800-447-1500, ext. 1133.**

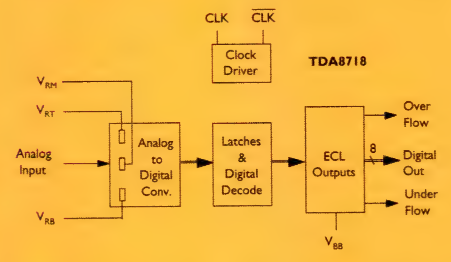

TDA8714 High Speed 8 Bit A/D

- 8 bit A/D
- 75 MHz minimum sample rate
- 7.7 effective bits @ 4.43 MHz input
- 14 pF input capacitance
- Binary output
- TTL I/0 and 3 state outputs
- Overflow/underflow 3 state output
- +5 V supply. 340 mW power dissipation
- 24 pin SO or SSOP


TDA8716 Very High Speed ECL A/D

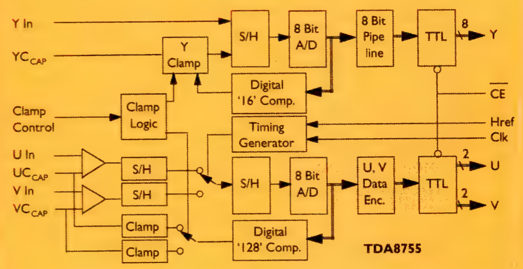
- 8 bit A/D
- 120 MHz minimum sample rate
- 7.7 effective bits @ 4.43 MHz input
- 13 pF input capacitance
- Binary or two's complement output
- ECL (10KH family) I/O
- Differential clock
- Overflow/underflow ECL output
- -5.2 V supply. 780 mW power dissipation
- 24 pin DIP or 32 pin SO

TDA8718 Ultra High Speed ECL A/D



- 8 bit A/D
- 7.5 effective bits @ 4.43 MHz input
- 600 MHz minimum sample rate
- 3.5 pF input capacitance
- Binary output
- ECL (100K family) I/O
- Differential clock
- Overflow and underflow ECL output
- 50Ω load drive capability
- -4.5 V supply. 990 mW power dissipation
- 28 pin PLCC

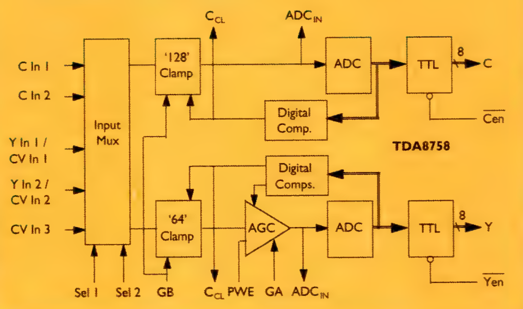
TDA8755 YUV A/D Interface



	U, V- Chroma	Y- Luma
Inputs	2:1	1
Clamp Level	'128'	'16'
Output	Two's Comp.	Binary
Differential Linearity	±0.5 LSB	±0.5 LSB
Sampling Rate (min)	20 MHz	20 MHz
Input Capacitance	1 pF	1 pF

Effective Bits @ 4.43 MHz	7.1
Crosstalk	-55 dB
Output Format	4:1:1
TTL I/O	Yes
Power Supply/Dissipation	+5 V/550 mW
32 pin SO Package	

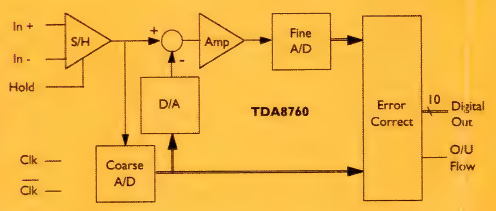
TDA8758 S Video Dual ADC



	C- Chroma	Y- Luma
Inputs	2:1	2:1 or 3:1 CV
Clamp Level		'128'
AGC (Sync = 64 LSBs)	'64'	
Peak White ≤ '255'	–	Yes
Amp Gain Range	–	Yes
Analog Bandwidth	–	-3 dB/+3 dB
Sampling Rate (min)	45 MHz	45 MHz
Effective Bits @ 4.43 MHz	30 MHz	30 MHz
	7.2	7.2

Crosstalk	
TTL I/O	-50 dB
Power Supply/Dissipation	Yes
48 pin TQFP Package	+5 V/485 mW

TDA8760 10 Bit ADC



- 10 bit A/D
- 8.8 effective bits @ 4.43 MHz full scale input
- Single ended or differential input
- Internal S/H
- Overflow/underflow indication
- 50 MHz minimum sample rate
- 4.5 pF input capacitance
- TTL logic, binary or two's complement output
- +5 V supply. 850 mW power dissipation
- 44 pin PLCC package

To learn more about all the advantages of running with the fast crowd of A-to-D converters, call today for a detailed product information package: **1-800-447-1500, ext. 1133.**

Philips Semiconductors

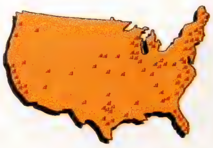
PHILIPS

Corporation 1994 Printed in U.S.A 98-1900-120 4130G/25M/FP/0694

OP ON THE ALLIED ELECTRONICS UPERHIGHWAY AND ENTER THE AST LANE!

Plot your course with the industry's first multimedia catalog. Choose from our traditional nted version or our leading-edge CD-ROM. Allied has merged two computer systems in one giving you on-line access to over 90,000 Allied parts and hundreds of millions of dollars of Avnet inventory. The Allied Superhighway navigates up-to-the-minute computer records for all your past transactions and present orders. Same day shipment receives a green light as your order is instantly entered. Payment is simple. Put your order on your Allied account, a credit card or pay COD. The Superhighway 800-number automatically routes you to your local Allied office, one of over 80 throughout the United States. Allied is different and the Allied Superhighway is designed to help make your job easier and faster. Call today and the Allied Superhighway will be built right to your door.

Same day shipment



More than 80 local sales offices

Multimedia catalog on CD-ROM

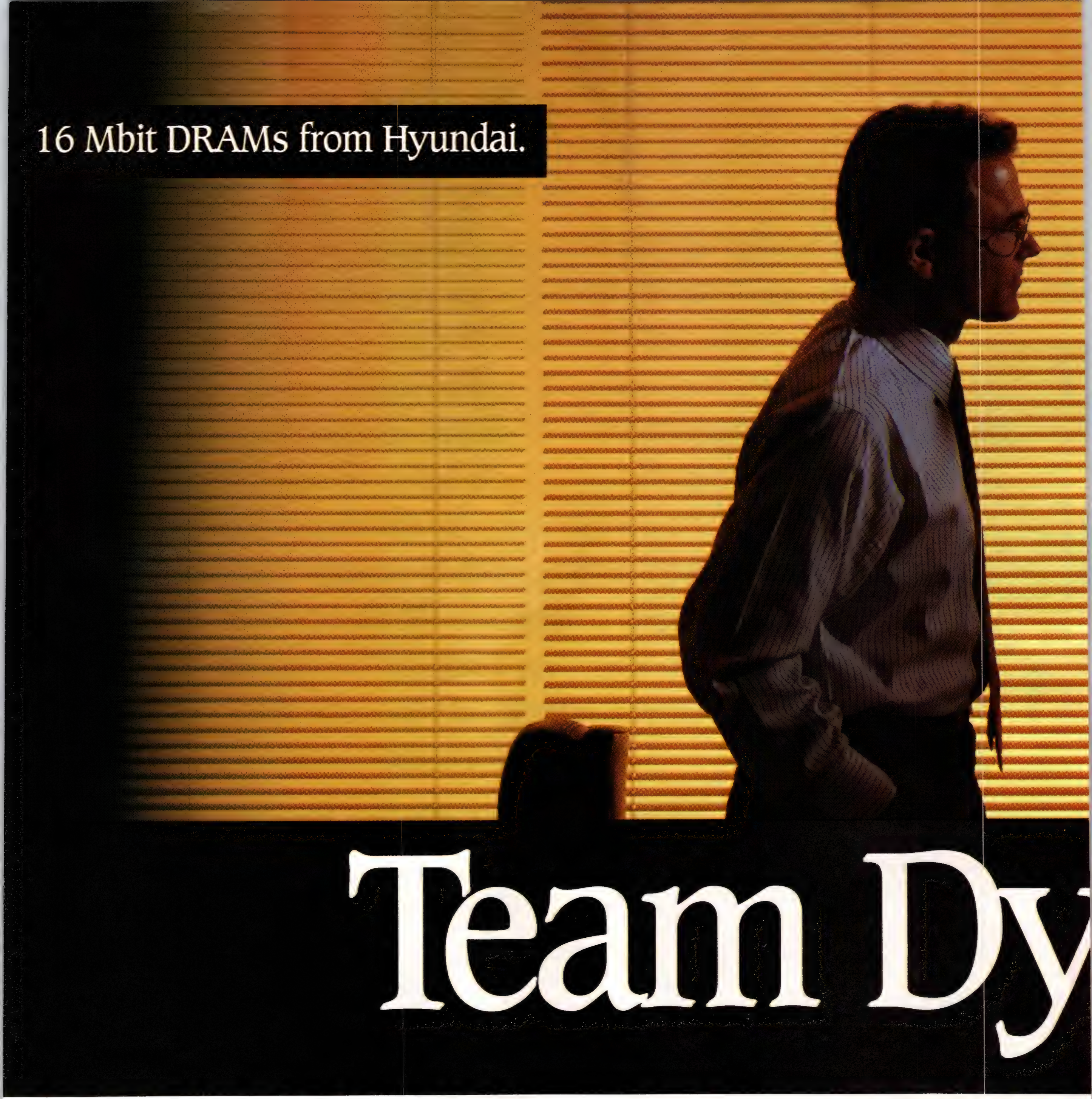
ALLIED ELECTRONICS INC.

AN AVNET COMPANY

Going by the book...And beyond!

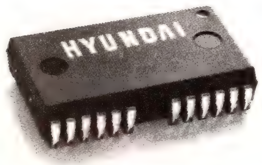
1-800-433-5700

CIRCLE NO. 92



16 Mbit DRAMs from Hyundai.

Team Dy



Sourcing used to be simple. The buyer and the design engineer got together for a few minutes. And that was it.

No more!

Now, virtually all of the make or break purchases for DRAMs and other major ICs in companies with over $10M in sales* are the result of a cross-functional team dynamic. And remember, no company has a bigger commitment to team dynamics than Hyundai.

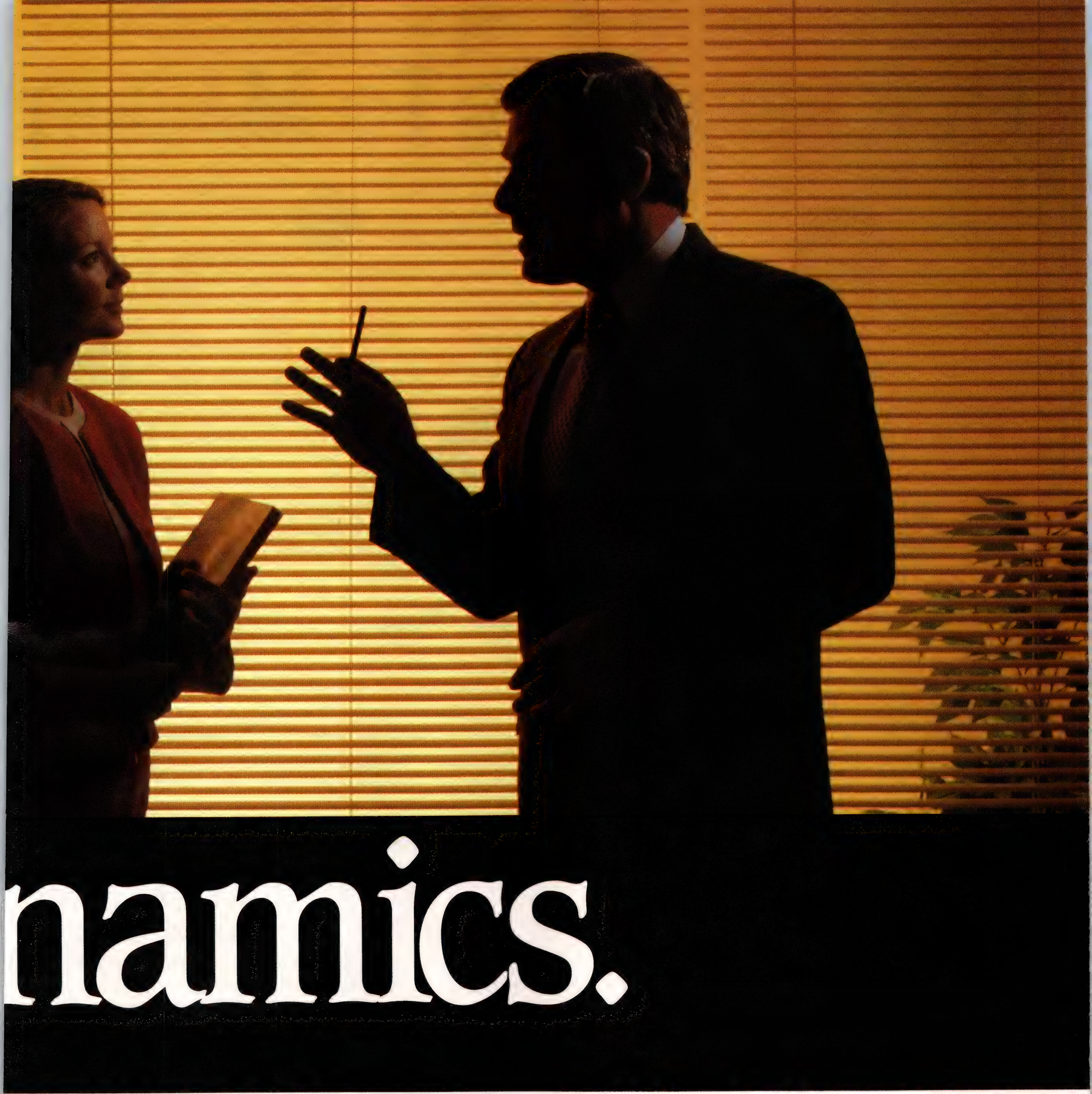
Hyundai knows the engineer needs better performance from the technology. Production must have qualified, readily obtainable parts. Purchasing has to get the best possible price and delivery. And management must build a long term strategic partnership with suppliers to obtain a superior competitive advantage.

Our new 16 Mbit dynamic RAMs are one more example of our dedication to the needs of the new team dynamic. We're committed to your success and the success of your cross-functional buying team through Hyundai's commitment to quality, reliability, manufacturing capability and value added pricing.

Your Hyundai DRAM Source Guid

Size	Part Number	Speed ns	Refresh Cycles/ms	Producti
16M x 1	HY5116100	60/70/80	4096/64	now
	HY5117100		2048/32	
4M x 4	HY5116400	60/70/80	4096/64	now
	HY5116410		4096/64, WPB	
	HY5117400		2048/32	
	HY5117410		2048/32, WPB	
2M x 8	HY5116800	70/80	4096/64	Q4 '94
	HY5116810		4096/64, WPB	
	HY5117800		2048/32	
	HY5117810		2048/32, WPB	
1M x 16	HY5116160	70/80	$2\overline{CAS}$, 4096/64	Q4'94
	HY5116260		$2\overline{CAS}$, 4096/64, WPB	
	HY5118160		$2\overline{CAS}$, 1024/16	
	HY5118260		$2\overline{CAS}$, 1024/16, WPB	

All available in standard and low power versions.
Packages include SOJ, TSOP II, reverse TSOP II.



New 16 Mbit DRAMs, designed with team dynamics in mind.

Evaluation samples of Hyundai DRAMs organized 16M x 1, 4M x 4 are available now. Coming soon are DRAMs organized 1M x 16 and 2M x 8. And many will operate off of a 3 volt source too.

Hyundai's new DRAMs feature speeds of 60, 70, or 80 ns. Immediately available, the HY5116100 and HY5117100 are organized 16M x 1 and provide 4096 refresh cycles per 64 ms and 2048 refresh cycles per 32 ms, respectively. New 4M x 4 parts include the HY5116400, with 4096 refresh cycles per 64 ms, the HY5116410 with write-per-bit capability, and the HY5117400 and write-per-bit capable HY5117410 offering 2048 refresh cycles per 32 ms.

All parts are available in standard and low power versions, dissipating 495 mW operating at 60 ns, 440 mW at 70 ns, and 385 mW at 80 ns. Other features include operation from a single 5V ±10% power supply, TTL compatible inputs and outputs, fast page mode operating, multi-bit test capability, read-modify-write capability, and CAS-before-RAS, RAS-only, as well as hidden refresh. Packages include standard 24/28 pin plastic, TSOP II, and reverse TSOP II. TSOP will be available soon.

These new parts are products of Hyundai's 0.55 micron CMOS process, at one of the most advanced electronics manufacturing plants in the world. So if purchase of 16 Mbit DRAMs is on your agenda, and you don't want to get caught short the way some did on 4 Mbit, start the team dynamics now.

Free 1994 16 Mbit DRAM Data Book.

Yours for the asking. Please phone, fax, or write for your copy today. Phone (408) 473-9274. Fax (408) 473-9370. Address Hyundai Electronics America, 166 Baypointe Parkway, San Jose, CA 95134.

Committed to your Success.

HYUNDAI

*Electronic Business Buyer

CIRCLE NO. 95

QUICKEST TIME TO MARKET

YOU KNOW QUICKLOGIC® IS THE FASTEST. NOW WE'RE THE EASIEST TO USE.

By using QuickLogic FPGAs, we guarantee your design can be realized faster than ever before.

GUARANTEED ROUTING

QuickLogic has such a wealth of routing resources in every *Wild*Cat™ FPGA that we guarantee utilization of up to 100% of the flipflops and I/O pins. And, with our Quick*Works*™ design tools, it's automatic — placing and routing a complex 4,000 gate design in under 10 minutes.

GUARANTEED PINOUT

With QuickLogic, you can *always* get to that pin. You can lock down your pins and hold them through multiple iterations — even with marketing surprises. No more costly board revisions and schedule slips.

$99 EVALUATION KIT — PUT OUR GUARANTEES TO THE TEST

Want proof with your own design? Call us now and we will send our new Quick*Works* suite of design evaluation tools for just $99.00. If you need more convincing, read on.

GUARANTEED TIMING

With QuickLogic's ViaLink® antifuse technology, logic interconnect impedance is so small that system clock speeds of 100MHz are easily attainable. Our AWE-based delay modeling software guarantees that your device will meet or exceed the reported timing.

GUARANTEED SYNTHESIS QUALITY

Rivaling schematic design entry in device speed and utilization, Quick*Works* introduces the highest quality synthesis for FPGAs. With Quick*Works*' Verilog® and VHDL synthesis (by Synplicity™, Inc.) and OVI-compliant Verilog simulation (by Simucad®, Inc.), quantum leaps in FPGA design productivity can be realized.

Take us up on our guarantee. Call for our tool set and get your design to market quicker. Fax us at **408-987-2012** or call **1-800-842-FPGA**(3742) for a QUICK response.

In *Europe*, call +49 (89) 899 143 28 or Fax +49 (89) 857 77 16.

QUICKLOGIC

We Live Up To Our Name

©1994 QuickLogic Corporation. QuickLogic and ViaLink are registered trademarks. *Wild*Cat and Quick*Works* are trademarks of QuickLogic Corporation. All other trademarks are the property of their respective companies. 104GD&A

CIRCLE NO. 104

Get ready to design with new-generation, BiCMOS-based 3.3V PLDs

RON CLINE, PHILIPS SEMICONDUCTORS

When designing with the coming generations of 3.3V PLDs, an understanding of the inherent characteristics of BiCMOS and pure-CMOS designs will help you optimize performance.

The 3.3V supply issue no longer applies solely to the portable notebook computer. Desktop computers continue to provide higher performance and increasing functionality; and, swelling gate counts have made power dissipation a serious concern in board designs. 3.3V μPs, memories, and gate arrays, optimized for the lower voltage supplies, are meeting the low-power challenge. However, high-performance 3.3V PLDs have been notably absent from the scene. This scenario will change as a new generation of BiCMOS-based PLDs comes to market. To exploit these new devices, you'll need insight into their inner workings, including the rationale underlying the use of BiCMOS vs pure-CMOS processing.

The bipolar transistors in BiCMOS can easily accommodate the lower supply voltage without compromises in performance. On the same silicon chip, CMOS logic can provide the functional density that's crucial for implementing the complex control logic necessary for programming the PLD. The new PLDs, coupled with industry-standard low-voltage BiCMOS logic devices, offer much-needed support for high-performance 3.3V systems. Before delving into the design and operation of the 3.3V PLDs, it's useful to review some aspects of the 5-vs-3.3V issue.

The 5V quandary

The needs of increasingly fast and complex systems have pushed 5V CMOS technology to its limit. In terms of performance, the upward drive of clock rates and the expanded use of high-throughput techniques, such as pipelining, have greatly increased the average switching frequency of on-chip nets. Power dissipation has suffered as a consequence, resulting in thermal-management problems in CMOS systems.

EMC and ground-bounce concerns have conspired to impose a limit on IC-pin edge rates. Although internal chip speeds have increased, improvements in pin-to-pin performance have become more difficult, especially for devices of lower complexity. Ever higher on-chip gate-count requirements are another important factor that puts a strain on IC-pin edge rates.

New processing equipment and technologies have created the capability of producing deep submicron devices with accompanying high-component densities, but at a cost. The breakdown voltages that come with 0.5-μm technology mandate the use of 3.3V supplies. For this reason, the 3.3V products tend to be leading-edge products in terms of chip complexity, for which the higher prices (and profits) can justify the expenses of process development and production equipment. Process technology, edge rates, and power dissipation have contributed to the movement toward high-performance 3.3V systems.

The PLD quandary

PLDs are in a special situation: The nature of PLD architectures, whether simple PAL-like devices or FPGAs, is such that CMOS-circuit performance can suffer greatly when supply voltages are reduced. This problem is especially disconcerting because product performance is up against a technological "wall" with 5V supplies (see **box**, "Reliability issues in CMOS ICs").

When a 5V CMOS design of a given level of technology is changed for 3.3V operation, the transconductance nature (voltage in, current out) of the MOS transistor imposes a reduction in available output current. This reduction occurs because the gate-input voltage swing is limited to the supply rails. It's possible to recover this current by increasing the size of the transistor, but this increase causes a larger load presented to the preceding stage. The result is a significant increase in delay.

The process engineer can partially compensate for the loss in transistor gain by reducing the channel length and the gate's oxide thickness. You can retrieve the rest of the performance loss by taking advantage of the reduced parasitics that accompany the tighter lithography in these processes. The tighter lithography and smaller resulting capacitances are the driving forces for the development of deep submicron processes. They allow for the design of higher gate-count ASICs with reasonable power dissipation and chip cost. Gate-array manufacturers are able to maintain 5V performance in 3.3V products by optimizing both process and cell design.

3.3V electrically programmable products face a unique problem when they use such optimized processes. To isolate the high voltages (>10V) needed to program the memory elements from the thin-gate-oxide transistors, one can use a second, thicker gate oxide for the transistors in the programming path. But, generating this high voltage with on-chip charge pumps is difficult without first raising the V_{DD} rail considerably above 3.3V, thus causing stress in the thin oxides. Increasing the charge-pump area can remedy this problem, but at a severe cost impact. The designer has to wait to see the road EPLD (erasable programmable logic device) vendors will take on their first 3.3V process-optimized products.

In contrast, the bipolar transistor is, for all intents and purposes, a current-gain device. Its base-emitter driving voltage is relatively constant, requiring only a few hundred mVs to shift the output from nonconducting to conducting. The required dc driving current—that the MOS transistor does not need—is provided by appropriate sizing of the input resistor **(Fig 1)**. In reducing the supply voltage from 5 to 3.3V, it's necessary to reduce the resistance accordingly.

Because the base current is the same in both cases, the dc power is reduced by the same factor as the supply voltage—roughly 34%. In **Fig 1**, however, the load capacitance can increase by 70%, to yield the same time constant at the collector. In this simplified example, the performance is equal to the performance obtained with 5V operation, with an increased capacitive load and decreased power consumption. Actual circuits have greater complexity, but the basic principal still holds.

This ability to handle high-current or -capacitance loads with small transistors applies most obviously to output buffers, which must drive pin or bus loads. (Unfortunately, board-trace capacitance doesn't scale with silicon technology.) Even on-chip circuitry benefits from this drive capability. Interconnect-wire capacitance, which tends to dominate in many portions of PLD circuitry, diminishes linearly with process shrinks, rather than according to the square law. As MOS transistors shrink, the parasitic overhead of interconnects looms larger.

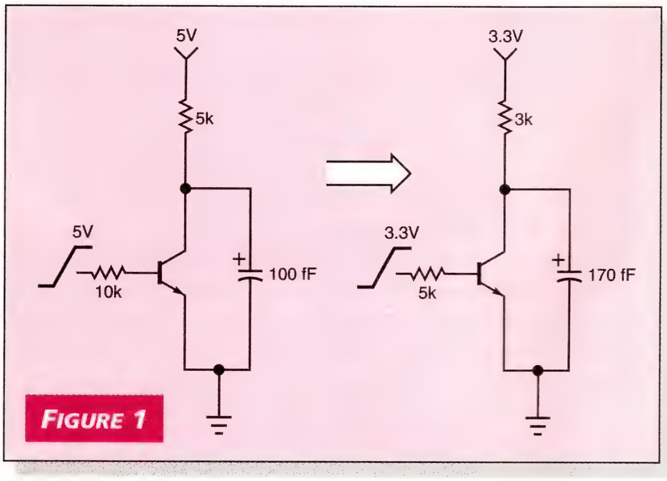


FIGURE 1

In converting bipolar circuits from 5 to 3.3V operation, it's necessary to change only the values of the passive components, not the transistor size.

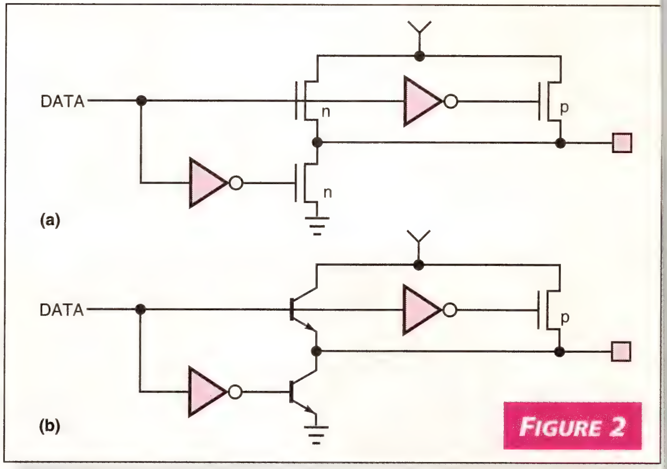


FIGURE 2

Both CMOS- (a) and BiCMOS-output (b) buffers need p-channel pullup transistors for rail-to-rail output swings. The source-follower MOS driver in (a) requires a 3 to 4X increase in transistor size for 3.3V designs; the size of the bipolar transistors in (b) remains unchanged.

Bipolar circuits share the common trait of consuming dc power. With ECL-based bipolar-circuit techniques, however, this power varies only slightly with input switching frequency, even at 100 MHz and higher. The dominant frequency-dependent power-dissipation component comes from the load capacitance at the output pins, not the internal circuitry. On-chip capacitances, the major component of dynamic power in CMOS circuits, are already accounted for in the current sources that are part of the ECL gates; no additional switching current is required. Consequently, ECL is the preferred architecture for implementing BiCMOS PLDs, except for the output buffer, in which a level translator reestablishes the proper CMOS levels.

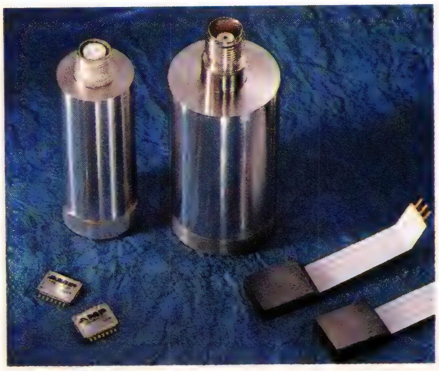
The bipolar transistor doesn't "know" that the supply voltage is lower. Its fundamental switching speed is maintained, even without process optimization for 3.3V operation. You can expect advances in process technology to improve the performance even further.

Bipolar transistors suffer by comparison in the area of functional complexity. High-performance bipolar-circuit approaches, such as ECL, rely on "stacked" transistors, each needing about 0.8V headroom to operate. With 3.3V supplies, it's possible to stack only two or three in series. The ability of CMOS circuits to implement complex gates, however, is unimpaired with lower supply levels.

The optimum solution is to use bipolar transistors in the data path, where multilevel, stacked gates are not needed, and use CMOS for the control logic needed in programming and test circuitry. This approach is already embodied in the design of high-performance 5V BiCMOS PLDs.

High-speed CMOS PLDs have traditionally specified TTL-level outputs, rather than rail-to-rail levels. This approach offers the advantage of reduced power dissipation at high output-switching frequencies. It also reduces the ground bounce appearing on unswitched low outputs, because the switching outputs pass less load charge through the package ground inductance.

Low-cost piezo-film accelerometers make life's ups, downs, and sudden turns manageable.



Off-the-shelf piezo-film accelerometers: our low-cost, high-performance packages are ready to design in, and available in volume.

The big news in sensors: our lineup of low-cost, high-performance accelerometers based on piezoelectric polymer technology. The good news for you: a big choice of off-the-shelf, ready-to-go sensors – in full production, with immediate availability.

Take a look at our very affordable single-axis versions for big-volume applications as diverse as car alarms, vibration/shipping-damage sensing, even musical instrument pickups. Small and lightweight. Buffered, low-impedance output. Wide frequency response and dynamite dynamic range.

If life keeps adding new twists, turn to our low-cost multi-axis types. Very small, very light, these true "smart sensors" are the smart choice for appliance, automotive, and security applications, and are already in use by the millions for disk drive shock sensing. Digital and analog output. Integrated, programmable electronics for filtering, amplification, and trigger-level control.

For needs beyond OEM, take a look at our instrumentation-grade, low-noise, high-output types, with fully integrated electronics (no charge amplifier or power supply worries). Very competitively priced. Ideal for demanding applications from machine health to modal analysis – or just about any spot you need a top-performance accelerometer.

We'd like to let you check out all the specs for yourself, and to help you get a handle on at least a few of life's ups and downs. Just call.

AMP is a trademark.

For more information, call 610-666-3500 (fax 610-666-3509). AMP, Harrisburg PA 17105-3608.
In Canada, call 905-470-4425.

AMP

CIRCLE NO. 3

For 3.3V products the output swing must be rail-to-rail in order to maintain acceptable system-noise immunity. Because this span leaves the output-voltage swing roughly the same as for 5V PLDs, the ground bounce remains substantially unchanged. BiCMOS PLDs have enjoyed an advantage in ground bounce and noise creation over CMOS at 5V operation; this advantage will remain with 3.3V operation.

Rail-to-rail swings also mandate the use of p-channel pullup transistors for both CMOS and BiCMOS designs (**Fig 2**). This structure provides the necessary dc drive to maintain high-level noise-threshold margins with the reduced supply voltage. Providing ac drive for the standard 50-pF load is more difficult for CMOS outputs at 3.3V.

Fig 2a shows that the normal technique in 5V designs is to use a source-follower n-channel device to drive the output pin high to threshold. The reduction in supply voltage dictates that this MOS transistor, if used, must be three to four times larger than in 5V designs to achieve the same driving capability. This larger geometry arises from the MOS transistor's need for high gate-source voltage to obtain reasonable values of current for a given transistor size. This voltage is reduced by more than half in comparison with voltage available in 5V designs.

Alternatively, a large p-channel transistor can drive the output directly, eliminating the n-channel device entirely. Either way, the load the output buffer presents to the internal chip is dramatically increased, compared with 5V designs. In contrast, the size of bipolar transistors in a BiCMOS output (**Fig 2b**) remains unchanged when redesigning output buffers for 3.3V applications. The bipolar device's current gain is independent of supply voltage; moreover, ac performance does not suffer from the redesign.

An indicator of BiCMOS performance is the recently released 3.3V family of LVT interface-logic products. The 74LVT240 octal three-state buffer is capable of driving a 35Ω transmission line in 4.2 nsec with a ground bounce of less than 0.8V with seven outputs switching. This bus-driving capability is admittedly a special case, but it does demonstrate the capabilities of BiCMOS processes.

Ground bounce is problematic for pure CMOS because of the bidirectional nature of the MOS transistor. An n-channel transistor that is capable of sinking a guaranteed 16 mA of output current is also capable of switching a 50-pF load in less than 2 nsec. Such a transistor, when switched on, is equivalent to a 10Ω resistor between the output pin and ground. This virtual short circuit couples any inductive spike appearing on the chip's internal ground line directly onto unswitched output pins. The MOS transistor's low resistance

RELIABILITY ISSUES IN CMOS ICS

If you're a designer of high-performance boards and need to use the fastest PLDs available, you should be aware of some issues that arise as technology is pushed to its limits. The topic, system reliability, elicits several well-known truisms in the industry.

The highest performance CMOS SPLDs (24 pins and smaller) wouldn't gain significantly from tighter interconnect rules or smaller transistors. The chip sizes are already fairly small and close to being pad-limited. The increased fabrication expense of going to a finer-pitch lithography would offset any cost savings ensuing from reduced-chip areas.

Size impact aside, it's still possible to affect process improvements to increase speed, and high speed is always in demand. The manufacturer of CMOS PLDs must be careful, however, to address transistor-lifetime issues. Hot-carrier-related (the same effect used in EPROMs to inject charge into the floating gate) wearout mechanisms gradually reduce the performance of MOS transistors in a predictable way. The normal effect of this transistor wearout is to increase thresholds and reduce current drive, thus degrading gate delays.

Some critical circuits, such as sense amplifiers, can become nonfunctional if they're not properly designed. These mechanisms are well understood, and, even if the process is pushed to its limit, proper analysis can ensure circuits that have predictable lifetimes. It's necessary to perform this study, carefully reviewing every individual transistor, for each new product using a given process. One class of exceptions: CMOS processes that are designed to satisfy hot-carrier lifetime requirements for all possible circuit implementations. Most 0.6-μm channel-length technologies satisfy this requirement in 5V devices.

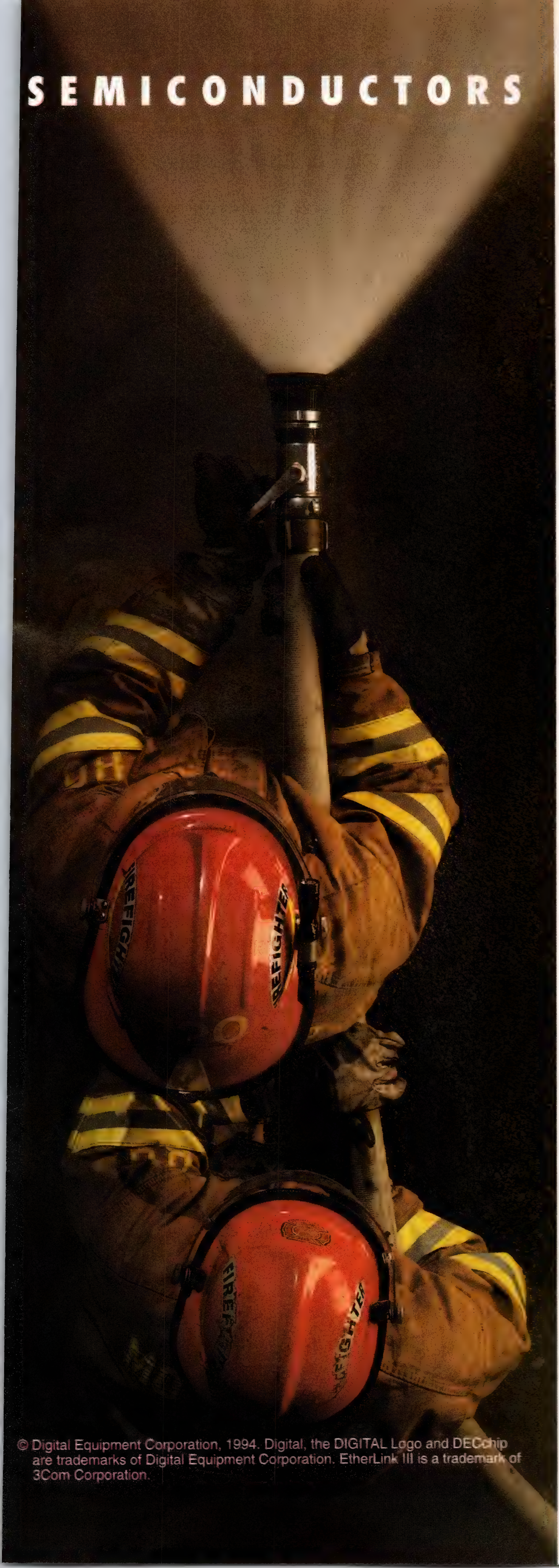
It is significant that the PLD chips most sensitive to this long-term speed degradation are those in the fastest speed grades. For a given chip design, the fastest product coming from fabrication is generally on the silicon with the shortest channel lengths. This same silicon has the greatest hot-carrier-dependent performance degradation, a correlation that is well-documented.

Reducing channel length alone, however, eventually produces diminishing returns in speed. For example, the reduction of channel length from 0.6 to 0.5 μm with 150A gate oxide improves n-channel MOS-transistor performance by less than 10%. Taking a more aggressive approach, reducing gate-oxide thickness is an effective way of improving MOS performance. But, reducing oxide thicknesses below a critical level is risky.

Long-term gate-oxide breakdown is strongly dependent on temperature and applied voltage. The breakdown voltage gradually decreases over time. This field/temperature-related lifetime is statistical in nature and linked to the uniformity of the gate oxide. The theoretical oxide thickness for 20-year lifetime—at 5.5V, 125°C—is 80A. It's commonly accepted within the industry that oxide thickness in production devices should not be reduced below 130 to 140A for 5V operation. Both oxide thickness and channel length are currently at their limits for reliable 5V products. Further improvements in MOS-transistor performance will be difficult to achieve.

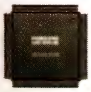
The best way you can assure yourself of long-term reliable performance is to ask your vendor to supply the manufacturing and design assumptions used for the product you're purchasing. Every manufacturer should have lifetime standards for processes and products, as well as the criteria for meeting those standards. Your vendor should be willing and able to provide this information.

SEMICONDUCTORS FROM DIGITAL

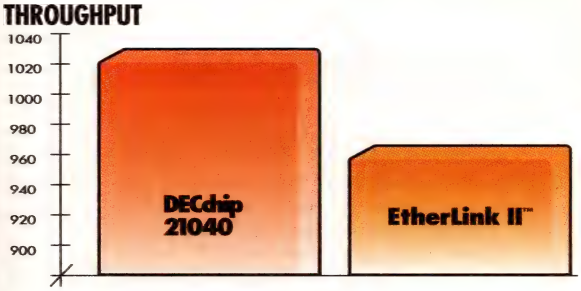


© Digital Equipment Corporation, 1994. Digital, the DIGITAL Logo and DECchip are trademarks of Digital Equipment Corporation. EtherLink III is a trademark of 3Com Corporation.

OUR NEW PCI ETHERNET CHIP PUMPS BITS LIKE YOUR LIFE DEPENDED ON IT.



When throughput is critical, hook up to our new 21040 PCI Ethernet controller chip and let the data flow. With our full 32-bit implementation, you'll get pure, unadulterated power. No 16-bit baggage. No bottlenecks. No compromises. And you'll get CPU utilization as low as 12%—low enough to support multiple Ethernet connections on a single NIC. This chip is fast. It's efficient. It's downright heroic. And it's just the beginning of a steady stream of PCI chips coming from Digital Semiconductor, the leader in PCI technology. Call us for more information. And hurry. The design you save may be your own.



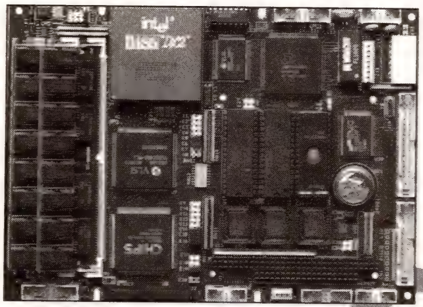
CALL 1-800-332-2717 EXT.17

digital™

The Nucleus of an Embedded System.

NPC-486™

PC/AT SINGLE BOARD COMPUTER



EMBEDDED-PC PC/104 MODULES

ACTUAL SIZE
5.75" X 8"

Made in the U.S.A.

ON BOARD ▶ ETHERNET ▶ VGA

▶ FLAT-PANEL SUPPORT
▶ 486 SX, DX, DX2
▶ 25, 33, 66 MHz
▶ 32 MB RAM
▶ SERIAL AND PARALLEL
▶ IDE AND FLOPPY
▶ KEYBOARD AND MOUSE
▶ RS-485 OPERATION
▶ SOLID STATE DISK
▶ WATCH-DOG TIMER

COMPETITIVE PRICES. EXCEPTIONAL SUPPORT.
OEM CUSTOMIZATION AVAILABLE.

ADASTRA SYSTEMS
28310 INDUSTRIAL BLVD. SUITE K. HAYWARD . CA 94545
TEL: 510.732.6900 FAX: 510.732.7655

CIRCLE NO. 110

PEARSON
Wide Band, Precision
Current Monitor

With a Pearson™ Current Monitor and an oscilloscope, you can make precise amplitude and waveshape measurement of ac and pulse currents from milliamperes to kiloamperes. Current can be measured in any conductor or beam of charged particles, including those at very high voltage levels.

A typical model gives an amplitude accuracy of +1%, -0%, 20 nanosecond rise time, droop of 0.8% per millisecond, and a 3 dB bandwidth of 1 Hz to 20 MHz.

Contact us for engineering data.

PEARSON
ELECTRONICS, INC.
1860 Embarcadero Road
Palo Alto, Calif. 94303, U.S.A.
Telephone (415) 494-6444
FAX (415) 494-6716

CIRCLE NO. 76

also contributes to the underdamped nature of the ringing that appears on such outputs.

By contrast, the bipolar transistor's on-resistance (also 10Ω) remains low only when current is flowing in one direction, from collector to emitter. If the current tries to flow in the opposite direction (in this case, from ground back into a static low output), the transistor immediately shuts off, breaking the path, and effectively damping the ground spike.

This inherent difference between MOS and bipolar transistors explains why, for equal output-edge rates, CMOS EPLDs are noisier than BiCMOS devices. This characteristic is independent of supply voltage, and is a design factor in some 3.3V systems. The VDD rail is as critical an ac return path as ground in 3.3V systems. It's important to look at "VDD bounce" as well as ground bounce when comparing different EPLDs. Data sheets should specify both.

The LVT22V10, soon to be in production, shares an important feature with its bus-interface cousins: forced-5V output capability. It's possible to raise output pins that are in a high-impedance state above their own 3.3V supply without loading down the bus. This feature is important when 3.3 and 5V chips are intermixed on the same board. BiCMOS technology implements this capability without a performance penalty.

The first 3.3V BiCMOS PLDs are slated to be manufactured in a 0.8-μm process. This generation of technology is conservative from a production standpoint and requires no new transistor structures. PLD delays of 7 nsec, and eventually 5 nsec, are feasible at this level of technology. As 0.6-μm process capabilities come to BiCMOS, you can expect further improvements in performance, with the same low power, rail bounce, and high reliability of the first-generation products.

CMOS products will enter the 3.3V high-performance PLD market using 0.5-μm MOS technology, because longer channel lengths won't yield the necessary transistor speeds. Implementation of nonvolatile elements at this level has yet to be demonstrated. Two high-quality, sub100A silicon oxides are required—one for the gate oxide and another tunneling oxide for the programming transistors. These requirements present significant challenges in wafer production.

By contrast, BiCMOS technology is now capable of delivering 5V performance in a 3.3V programmable-logic device without pushing process technology to the limit. The inherent advantages of low-noise outputs, reduced power dissipation, and load-driving capability promise to make BiCMOS a worthy contender in high-performance PLDs. EDN

Author's biography

Ron Cline is a design manager in the programmable logic division of Philips Semiconductor, where he has worked for 18 years. His accomplishments include designing the first commercially successful PLD, the 82S100 FPLA, in 1975. Cline received a BSEE from the Massachusetts Institute of Technology in 1971. He is a member of the IEEE. You can contact him via Internet at "cline@scs.philips.com."

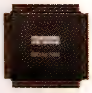
VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

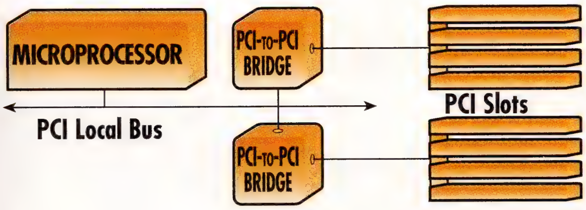
High Interest	Medium Interest	Low Interest
589	590	591

EMICONDUCTORS FROM DIGITAL

EXPAND YOUR PCI OPTIONS WITH OUR NEW PCI BRIDGE CHIP.



Is your design sidetracked by PCI load limits? Let Digital Semiconductor's new 21050 PCI-to-PCI Bridge chip get things rolling. It's the only PCI-to-PCI bridge available today. And it frees you from PCI loading limits for good. Motherboard designers can use it to implement as many PCI slots as they will ever need. Expansion card designers can use it to add multiple PCI components – for highly integrated multimedia, RAID, and LAN designs. It's easy. It's powerful. It's from the company that invented PCI-to-PCI bridging.

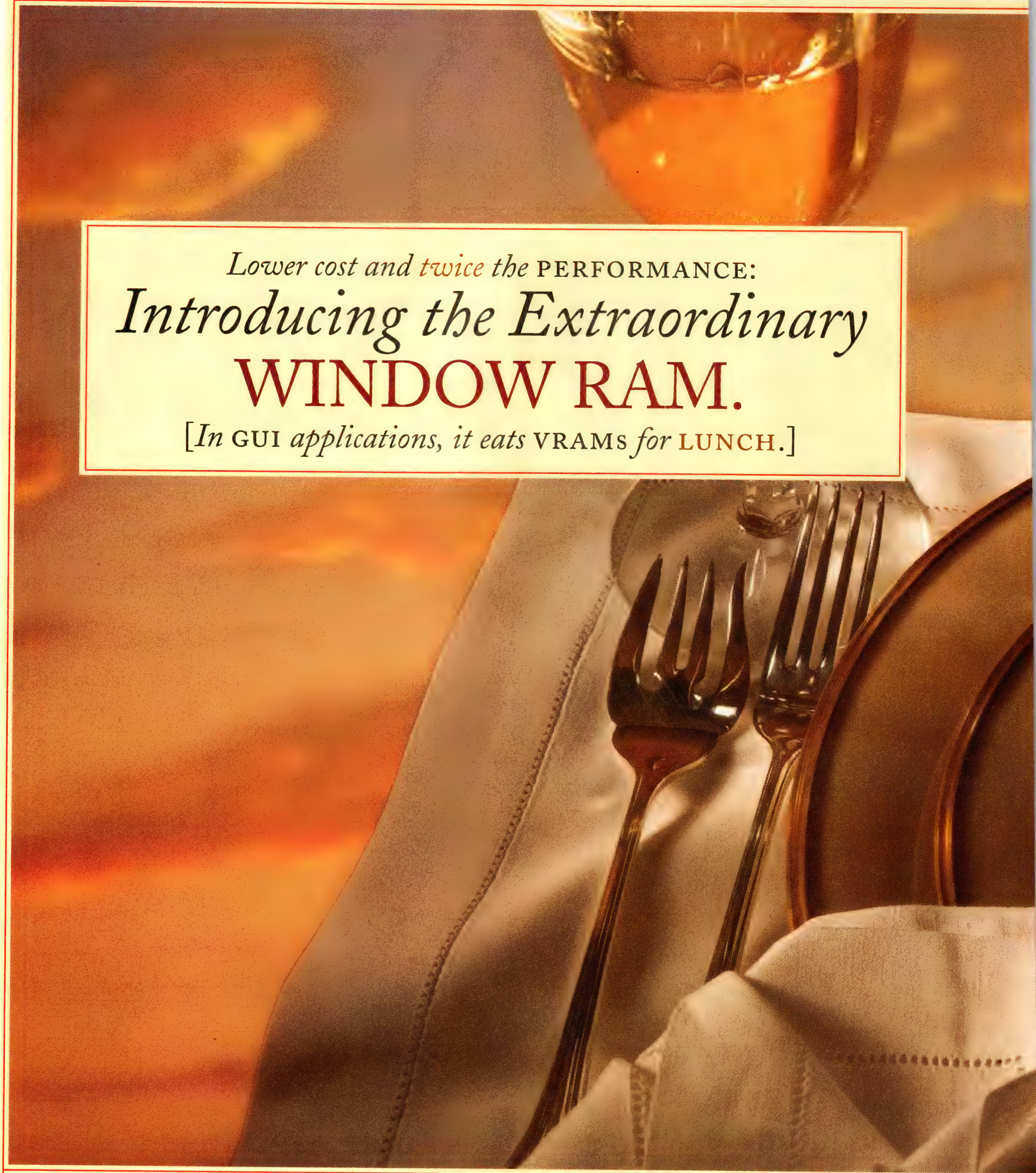


Call Digital Semiconductor for more information about our PCI Bridge and our other PCI chip products. Then get ready to open up some new territory.

CALL 1-800-332-2717 EXT. 18

digital™

© Digital Equipment Corporation, 1994. Digital and the DIGITAL Logo are trademarks of Digital Equipment Corporation.



Lower cost and twice the PERFORMANCE:

Introducing the Extraordinary WINDOW RAM.

[*In* GUI *applications, it eats* VRAMS *for* LUNCH.]

Nowadays, graphical user interfaces are everywhere. But they're also terribly slow.

We at Samsung decided it was time somebody fixed that.

Which is why we've designed a new product—with a new architecture—that not only outperforms VRAMs* but sells for much less.

The 8-Mbit Window RAM gives you a 1024 x 1024 x 8-bit frame buffer.

Its 20 ns extended data out Fast Page Mode will give you a minimum of 33% more speed than the fastest VRAMs. And the Window RAM incorporates several dedicated GUI-accelerating features. All of which means that—yes—it eats VRAMs for lunch.

You'll find that the Window RAM's familiar interface makes designing with it easy. And you'll also find that a new generation of graphics controllers will support it. So you'll not only be able to put the Window

---

*SURPASSES VRAMS IN PERFORMANCE BY UP TO 180% IN BENCHMARKS. © SAMSUNG SEMICONDUCTOR, INC., 1994.

Samsung's Highly Innovative WRAM *(and Also Our* VRAMs.)

PART	ORG.	ACCESS TIME	ULTRA FAST PAGE CYCLE TIME	VOLTAGE
KM4232W259	256K x 32	60 ns	20 ns	5.0V
KM4232X259	256K x 32	60 ns	20 ns	3.3V

WRAMs *in 120-pin PQFP. Also available: our state-of-the-art 1-meg and 2-meg* VRAMs: KM4216C256 *and* KM4216C258 *(both 256K x 16),* KM428C256 *and* KM428C257 *(both 256K x 8), in both 5 and 3.3 volt.*

RAM to use, you'll be able to do it almost effortlessly.

We're able to offer the chip at a low *cost* because of its streamlined design, which eliminates the unused overhead that comes with VRAMs—such as serial write, write transfer, and flash write.

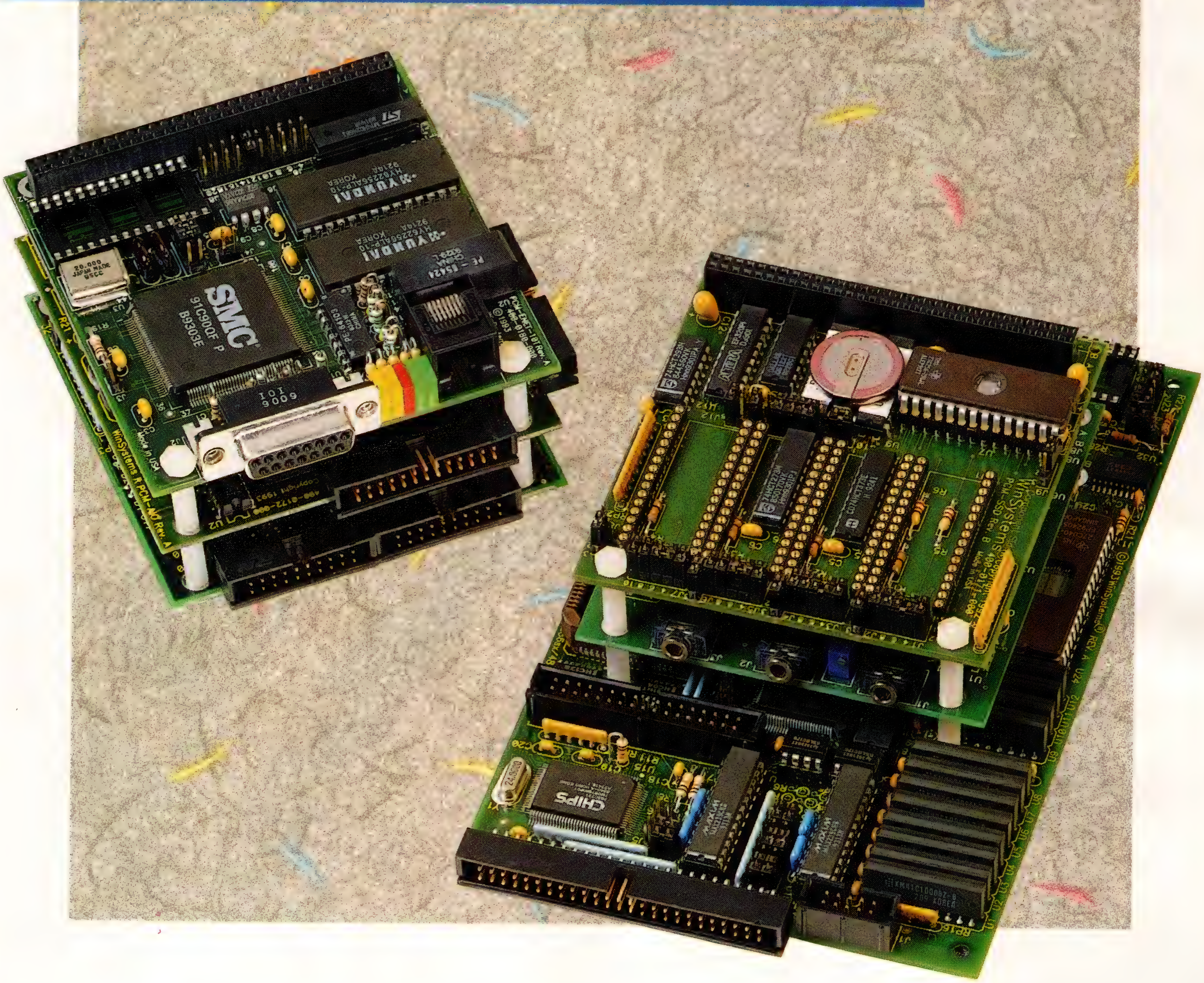
And with this kind of performance at this kind of cost, we're confident the Window RAM will be chowing down on VRAMs for some time to come.

For information on designing-in this latest piece of memory wizardry from Samsung, call 1-800-446-2760 or 408-954-7229 today. Or write to WRAM Marketing, Samsung Semiconductor Inc., 3655 N. First St., San Jose, CA 95134.

SAMSUNG
SEMICONDUCTOR
A *Generation* AHEAD.

CIRCLE NO. 105

PC/104™ Embedded PCs



PC/104 expandable PCs are the practical way to embed the PC architecture in space- and power-sensitive applications. By standardizing hardware and software around the broadly supported PC architecture, you can save substantial development costs, risks, and time.

Rugged, reliable, and built for -40°C to +85°C temperature environments, these compact computers go where most others cannot. You'll find that our embedded PCs and assorted PC/104 modules offer you a standard PC-compatible platform at a fraction of the cost of a custom design with additional features.

The ultra-compact PC/104 modules can be stacked atop each other or as a mezzanine bus on a larger embedded PC. WinSystems offers both busless embedded single board computers with PC/104 expansion and also computers with a hybrid of both STD Bus and PC/104 bus support.

Call or write for a *free* Catalog.

EMBEDDED-PC PC/104 MODULES™

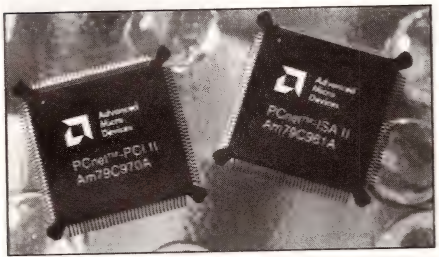
WinSystems®

CIRCLE NO. 157

715 Stadium Drive • Arlington, Texas 76011 • Phone 817/274-7553 • FAX 817/548-1358

FREE INFO, FREE POSTAGE
Use our postage-paid reader-service cards to get more information on any of these products.

Fast Ethernet-controller chip links to PCI bus. The DECchip 21140 PCI Fast Ethernet-LAN controller has both 100- and 10-Mbps ports, allowing system designers to create upgradable systems. The controller features NWay full-duplex autodetection, flash-memory support, and support for universal-voltage PCI systems. The new chip is driver-compatible with the previous 21040 device. Sampling now with production quantities scheduled for 1995. $39.50 (5000). **Digital Equipment Corp**, Maynard, MA. **Circle No. 302**



Single-chip Ethernet controllers for PCI and ISA buses provide full-duplex operation. You can program the PCnet-PCI II and -ISA II chips to operate in either half- or full-duplex mode. They are pin- and software-compatible with their PCnet predecessors, PCnet-PCI and PCnet-ISA+. The devices accommodate 10Base-2 or -T wiring and contain power-management features, including two sleep modes. PCnet-PCI II costs $29.95 (1000), and PCnet-ISA II costs $25.75 (1000). **Advanced Micro Devices Inc**, Sunnyvale, CA. (408) 732-2400. **Circle No. 303**

128-kbit EPROM is available in 45- to 200-nsec speed grades. The CY27C128 consumes 248 mW when operating and 83 mW in standby operation. The devices are available in 28-pin DIP and 32-pin PLCC packages. A 120-nsec part in a plastic DIP is $2.25 (5000). **Cypress Semiconductor**, San Jose, CA. (408) 943-2600. **Circle No. 304**

Controller chip for touch panels offers 1024×1024-element resolution. The 10-bit controller for analog and digital touch-control panels provides automatic self-calibration and a power-saving mode. Packaged in a 64-pin QFP, the IC costs $20 (100). **Global Components Corp**, Floyds Knobs, IN. (812) 923-1000. **Circle No. 305**

Low-cost G.728 audio-compression IC. The PSB 7280 joint audio decoder and encoder costs $30 (50,000) and provides a low-cost alternative to using a high-performance, general-purpose DSP chip. The IC integrates a 16-bit fixed-point DSP plus additional on-chip circuitry specifically designed to implement the G.728 algorithm. The IC also provides a serial interface for video codec chips and an ISDN-oriented module interface for telecommunication chips. **Siemens Components Inc**, Cupertino, CA. (408) 257-7910. **Circle No. 306**

RAMDACs for high-performance, true-color applications. The KDA0484 and 0485 are pin-compatible replacements for the Brooktree Bt484

SystemView™
BY ELANIX

SystemView - [c:\systemvu\examples\costas.svu]
File Edit Preferences View NotePads Connections Tokens Help
SystemView Linear System - (BandPass FIR)
SystemView BandPass Filter Design
FIR Filter (BandPass)
Gain (dB)
No. FIR Taps
OK
Cancel

FREE SystemView evaluation disk. Call for yours today.

Workstation power on your PC. Performs in the familiar Microsoft Windows environment.

PERSONAL DYNAMIC SYSTEM SIMULATOR: Powerful. Intuitive. And instantly productive.

MICROSOFT® WINDOWS™ COMPATIBLE

Bringing workstation-level design, simulation and analysis tools to your PC. Intuitive, powerful and dynamic, SystemView thinks like you do. And with its easy-to-use graphical user interface, there's no code to learn!

The industry's most flexible and versatile system design tool for today's applications:
- **DSP systems**
- **Communications**
- **Signal processing**
- **Control systems**

Industry-leading features include:
- Analog, digital, mixed mode, and multi-rate system development
- Linear and non-linear system design
- Laplace and z-domain linear system specification.

Join the enthusiastic users in industry and in universities worldwide...Discover SystemView: the most powerful system design tool available today.

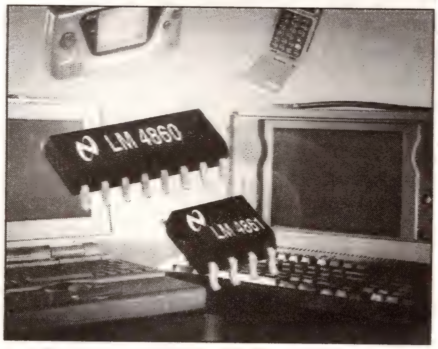
Call ELANIX now. **1-800-535-2649**

5655 Lindero Canyon Rd., Suite 304 • Westlake Village, CA 91362 • (818) 597-1414 • Fax (818) 597-1427. © ELANIX, Inc. 1994. SystemView by ELANIX is a trademark of ELANIX, Inc.

CIRCLE NO. 94

and 485 and AT&T's ATT20C504 and 20C505 RAM DACs. The KDA0486 provides a 24-bit packed-pixel mode with 4:3 multiplexing and support for a 16-bit pixel bus. The 24-bit packed-pixel mode transfers 1⅓ pixels in each 32-bit bus cycle. Other RAMDACs waste 8 bits per bus cycle. The chip also works with a single-chip, 1-Mbyte Window RAM 16-bit interface without external logic. An 85-MHz KDA0484 is $12.10 (100), the 110-MHz KDA0485 is $14.90 (100), and the KDA0486 is $17.85 (100). **Samsung Semiconductor Inc**, San Jose, CA. (408) 954-7000. **Circle No. 307**

Digital-video chip set includes five devices. Designed for interfacing with CCD sensors, the chip set includes the H8/337 embedded controller for managing system functions, the HA118144 CCD interface with correlated double sampling and automatic gain control, the HD49306 9-bit A/D converter that digitizes the video signal, the HD49801 DSP, and the HD49803 timing generator. The HMM49101 production chip set with a ROM-based H8/337 costs $65 (10,000), and development chip sets with a OTP H8/337 cost $95 (10,000). Optional chips provide electronic zoom and analog outputs. **Hitachi America Ltd**, Brisbane, CA. (800) 285-1601, ext 05. **Circle No. 308**

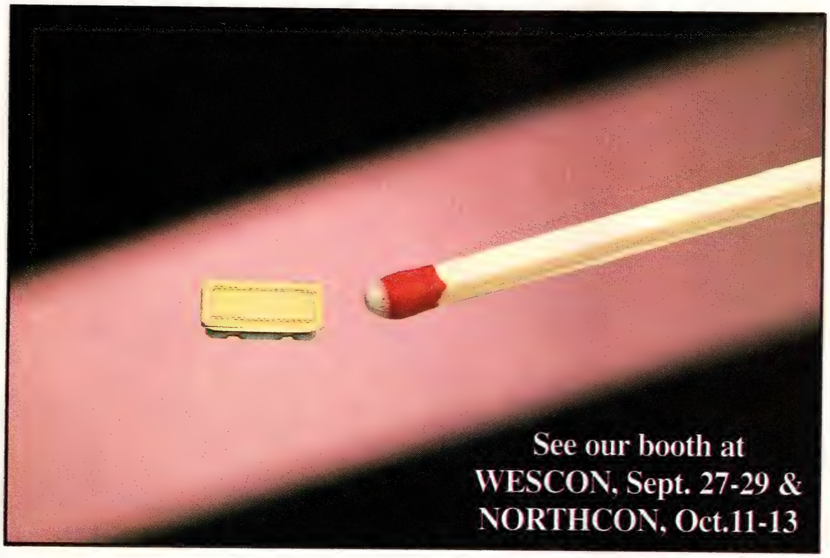


5V audio power amplifiers deliver 1W to 8Ω loads. The LM4860 has <1% THD plus noise and operates from power supplies as low as 2.7V. A shutdown mode reduces supply current to <1 μA typ. The device also has headphone sensing that sets a status flag and provides muting when headphones are plugged into the system. The LM4860 costs $1.99 (1000), and the 500-mW LM4861 costs $1.89 (1000). **National Semiconductor Corp**, Santa Clara, CA. (800) 272-9959. **Circle No. 309**

Single-chip MPEG-1 decoder. The IIT320 multimedia playback processor (MPP) requires only memory and D/A converters for a complete system in PC add-in cards or embedded applications. The MPP can decode the MPEG system layer, MPEG-1 video at SIF resolution, and two channels of MPEG-1 layer 1 or 2 audio. On-chip multitap filters provide arbitrary video scaling, video-standard conversion, and postprocessing. On-chip interlacing filters eliminate the need for video overlay or scaling devices and provide good picture quality using low-cost video DACs. $37 (1000). **Integrated Information Technology Inc**, Santa Clara, CA. (408) 727-1885. **Circle No. 310**

Trio of chips suit digital video and multimedia applications. The KS0116 Genlock digitizer $10.65 (100) and KS0117 NTSC decoder $11.40 (100) provide a complete video-capture chip set for obtaining industry-standard CCIR 601 video data from a vari-

Our Performance
. . . Is Matchless!



Ecliptek Introduces the ECCM2 2.5 MM Ceramic SMT Crystal for PCMCIA

- Designed For All PCMCIA Applications
- Common Chipset Specifications In Stock
- Frequency Range From 3.500MHz to 70.000MHz
- Tape And Reel Standard For Automatic Insertion

Crystals • Clock Oscillators • Inductors

To Access All Ecliptek Current Data Sheets,
& Our Fax-On-Demand System
1-800-ECLIPTEK

ECLIPTEK® CORPORATION
Fax: (714) 433-1234
3545 Cadillac Ave. • Costa Mesa, CA 92626

CIRCLE NO. 32

Ethernet LAN ICs

Make your laptop adapt.

If you're designing laptops you know it better than anyone. Computer users want portable models to do all the tricks their desktop cousins do. Not the least of which is Ethernet LAN connectivity.

That's why Silicon Systems is offering the lowest power LAN ICs you can get, including Ethernet ICs that are ideal for Type 1 PCMCIA cards. Thin Quad Flatpack (TQFP) packages that perform mightily while standing just 1.4mm high.

Our 78Q8373, for example, offers everything from a 10Base-T transceiver to PCMCIA interface and highly sophisticated power management circuitry. All on one chip. Or there's our supurb new 78Q8330, which is perfect for thin Ethernet coaxial cable 10Base-2 applications. In fact, our whole family of laptop LAN ICs gives you nothing less than optimum performance while holding down cost and foot print size.

All facts which are pretty easy to adapt to. So find out more about the first family of Ethernet LAN ICs for laptops.

Call us for literature package **CPD-16.**

If you'd like, we'll also tell you how to contact your nearest Silicon Systems representative. **1-800-624-8999, ext. 151.**

Silicon Systems, Inc.
Communications / Industrial Products Division
14351 Myford Road, Tustin, CA 92680
Ph (714) 573-6000 Fax (714) 573-6906

silicon systems®
A TDK Group Company

CIRCLE NO. 84

TestPoint is a software tool for building test, measurement, and data acquisition applications for Windows. TestPoint lets you build complete applications without drawing, connecting, or wiring icons or writing lines of code.

New Capabilities
TestPoint brings extraordinary capability to instrument control and data acquisition for the benchtop or production line. TestPoint's software functions can replace hardware functions worth thousands of dollars, provide new measurement capabilities and simplify testing.

Better Tests
Sharp graphics and clear indicators eliminate errors and improve accuracy.

Cut Through the Paperwork
TestPoint can "hot link" to your spreadsheets, databases and word processing files so the paperwork is done the instant the test is finished.

There is no faster, better or easier way to build applications. Guaranteed!

- **Data Acquisition**
  Multitasking A/D, D/A, Digital I/O
- **Instrument Control**
  IEEE-488, RS232, RS485
- **Analysis**
  Mathematics, DDE
- **Presentation**
  Graphics Charts
  Displays File I/O

Development System $995
Free Unlimited Runtime License
Literature 1-800-234-4232
Applications 617-273-1818

cec
Capital Equipment Corp.
76 Blanchard Road
Burlington, MA 01803

TestPoint is a trademark of Capital Equipment Corp.

CIRCLE NO. 138

ty of sources, including standard roadcast NTSC signals from tuners, aser-disk players, signal generators, nd VCRs. The KS0119 NTSC encoder 12.90 (100) combines NTSC encoding vith conventional RAMDAC functions o display a variety of digital video-nput formats on NTSC or RGB analog monitors. **Samsung Semiconductor** nc, San Jose, CA. (408) 954-7000.

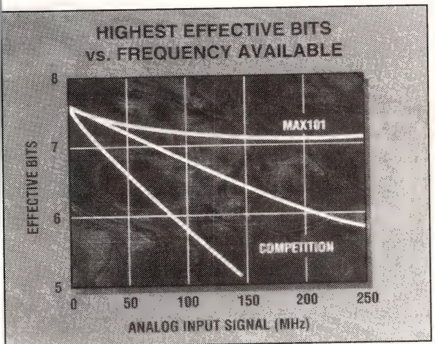
Circle No. 311

noise. The outputs of the IC remain in a high-impedance state while the power supply ramps up from 0 to approximately 2.1V for graceful power-up sequences during live insertion. The 28-pin PLCC is $9.30 (1000). **Philips Semiconductors**, Sunnyvale, CA. (800) 447-1500, ext 3000.

Circle No. 314

BiCMOS op amp combines high speed with high input impedance. The TSH321 offers a 400-V/μsec slew rate, 300-MHz gain-bandwidth product, and a typical input current of 2 pA. Unlike JFET devices, the input current does not increase rapidly with temperature. The amplifier operates from ±3 to ±7V supplies and drives 50Ω loads with up to 100-mA output current. Settling time to 0.1% is 60 nsec. The op amp is available in eight-pin DIP and SO packages. $2.50 (1000). **SGS-Thomson Microelectronics**, Lincoln, MA. (617) 259-0300.

Circle No. 315



8-bit 500M-sample/sec ADC delivers 7.1 effective bits at Nyquist frequency. The MAX101 includes a track-and-hold amplifier and ADC with a 1.2-GHz input bandwidth and aperture jitter of <2 psec. Erroneous code outputs happen <1/10^{15} clock cycles, and, when they occur, the magnitude of the error is <1 LSB. The MAX100 provides similar performance at 250M samples/sec. From $265 (100). **Maxim Integrated Products**, Sunnyvale, CA. (408) 737-7600, ext 6087.

Circle No. 312

Fast 8-bit ADC family digitizes at up to 600M samples/sec. The TDA8718 has a usable input bandwidth of 150 MHz and digitizes at 600M samples/sec. The device is ECL-100k compatible and dissipates 1W from a –4.5V supply. Packaged in a 28-pin PLCC, the device costs $539.91 (100). The 75M-sample/sec TDA8714 is TTL-compatible, dissipates 325 mW from a 5V supply, and costs $18.55 (100). The 50M-sample/sec TDF8704 is also TTL-compatible, dissipates 360 mW from a 5V supply, and costs $6.48 (100). **Philips Semiconductors**, Sunnyvale, CA. (800) 447-1500, ext 3000.

Circle No. 313

7.5-nsec 22V10 PLD operates from 3.3V supplies. The LVT22V10 is compatible with both 3.3 and 5V inputs and outputs, tolerates live insertion, and uses an active feedthrough cancellation technology to reduce output

Create Custom PC Applications Without Custom Programming!

VISUAL DESIGNER™
BEYOND PROGRAMMING . . .

NOW WITH GPIB, SERIAL AND MORE DSP!

For Test, Measurement, Control & More.

Acquire Your Data in Just Two Steps
Create the applications you need—without programming! Visual Designer is a revolutionary, new software development tool. With it you'll save days, weeks, even months of development time. To create your application just select the appropriate function blocks, and then connect them with your mouse. Test, measurement, control, streaming data to disk, spectrum analyzers, strip chart recorders, instrument panels—and much more. It's that simple.

Your Complete Solution $995!
Buy Visual Designer and our new low-cost data acquisition board by Dec. 30, 1994 and save $455! You'll get Visual Designer, the PCI-20428W and a termination panel for just $995. Best of all, the board comes complete with a lifetime warranty.

PCI-20428W Low-Cost Data Acquisition Board
- 16SE/8Diff Analog Inputs, 100kHz
- Gains (1, 2, 4, 8) or (1, 10, 100)
- 2 Analog Outputs, 100kHz
- 1 Counter/Timer, 2 Rate Generators
- 8 Digital Inputs, 8 Digital Outputs
- DMA Channels for Analog I/O
- Streaming to Disk/Transient Capture
- List Price: $395 (without termination)

Order Today!
Call (800) 685-9911, Operator 619

Fax: Attention 619, (602) 573-0522
Mail: Intelligent Instrumentation
Order Desk 619
6550 S. Bay Colony Dr., MS130
Tucson, AZ 85706

MICROSOFT® WINDOWS™ COMPATIBLE

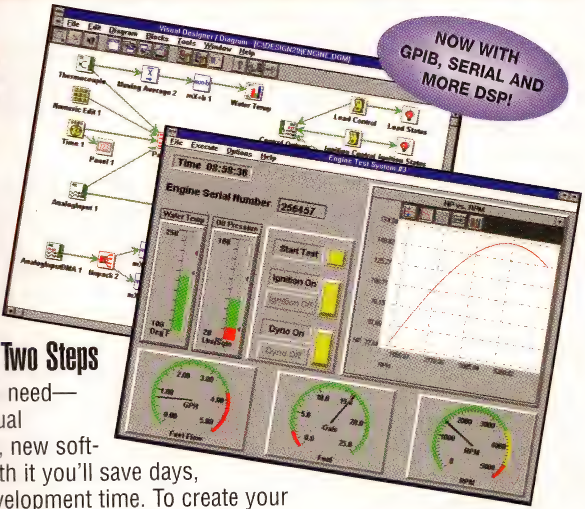
INTELLIGENT INSTRUMENTATION™
A Burr-Brown Company BB®

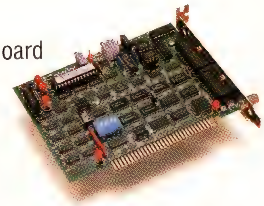
ISO 9001 CERTIFIED

INTERNATIONAL OFFICES:
France • Germany • Italy • Japan • United Kingdom

Visual Designer™, Intelligent Instrumentation, Inc.; Windows®, Microsoft Corporation.

CIRCLE NO. 39





FREE INFO, FREE POSTAGE
Use our postage-paid reader-service cards to get more information on any of these products.

Filter-design program lets you interactively design FIR and IIR filters. DF Designer runs under Windows and creates digital filters to meet your specifications. The program also generates frequency-response plots. $295. **Sigsoft**, San Diego, CA. (619) 673-0745. **Circle No. 316**

Electronic load lets you test power supplies for stability. The EL-1132 dc electronic load lets you control the resistance, current, and voltage of a power supply under test. The supply has a range of 0 to 60A, 2.5 to 60V dc, and 300W. For dynamic load testing, the electronic load has a programmable slew rate of 6A/μsec. The unit can operate stand-alone or be controlled through IEEE-488 or RS-232C interfaces. From $1795. **American Reliance Inc**, Arcadia, CA. (818) 303-6688. **Circle No. 317**

DSO provides 12-bit resolution. The DataSys 840 digital storage oscilloscope (DSO) provides four channels with 12-bit resolution and low noise for measuring signals with a wide dynamic range. In the 12-bit mode, the DSO samples at 10M samples/sec and has a 5k-word memory/channel. The DSO also operates in an 8-bit mode at 100M samples/sec with a 50k-word memory. An antialiasing input filter preserves data integrity and couples to the timebase to remove high-frequency signals that could cause aliasing. From $13,990. **Gould Instrument Systems Inc**, Valley View, OH. (404) 328-7263. **Circle No. 318**

Signal-conditioning hardware suits PC-based data-acquisition systems. The DBK series of compact boards and modules for PC-based data-acquisition systems provides signal conditioning for thermocouple measurement; strain-gauge measurement; current measurement; RTD measurement; simultaneous sample and hold; lowpass filtering; and isolated volt, temperature, and strain measurement. Multiplexing cards also provide dynamically programmable gains. Prices for the cards range from $195 to $1695. **IOtech Inc**, Cleveland, OH. (216) 439-4091. **Circle No. 319**

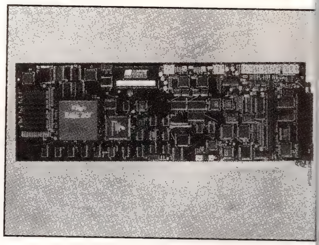
PC-based DSO board and software offer 500-Hz repetitive-sampling rate. The PCIP-Scope provides a PC-compatible data-acquisition board plus Windows-compatible software to function as a two-channel digital storage oscilloscope (DSO). The software provides a 500M-sample/sec effective sample rate for repetitive waveforms. For a single event, the maximum sample rate is 20M samples/sec. The product costs $1099. A software upgrade is $100. **Keithley Metrabyte**, Taunton, MA. (508) 880-3000. **Circle No. 320**

Portable data-acquisition system has 16-bit resolution and offers an internal expansion slot. The DaqBook/216 interfaces to a notebook computer through the parallel port and samples eight differential or 16 single-ended analog channels at 100 kHz. The unit also has two 12-bit analog outputs, four digital inputs, four digital outputs, and one counter-timer. The internal expansion slot accepts any of the company's DBK option cards for signal conditioning. $1695. **IOtech Inc**, Cleveland, OH. (216) 439-4091. **Circle No. 321**

LCD digital panel voltmeter has small form factor and low cost. The DMS-20LCD Series digital panel voltmeters provide 3½ digits in a 1.38×0.88 ×0.42-in. package. You can read the 0.37-in. high-contrast display from 10 ft away. The display comes in ±200-mV and ±2, ±20, and ±200V voltage ranges and costs $24 (100). **Datel Inc**, Mansfield, MA. (508) 339-3000. **Circle No. 322**

CDMA spectrum analyzer is compatible with the IS-95, -97, and -98 test standards. The CDMA portable spectrum analyzer combines the HP 85725A CDMA measurement's personality and an HP 8590 E-series spectrum analyzer. The measurement personality controls the analyzer settings, measures the signal parameters, and calculates the results. Results display numerically and graphically. A typical configuration with frequency coverage to 2.9 GHz costs $20,000. **Hewlett-Packard Co**, Santa Clara, CA. (800) 452-4844, ext 8544. **Circle No. 323**

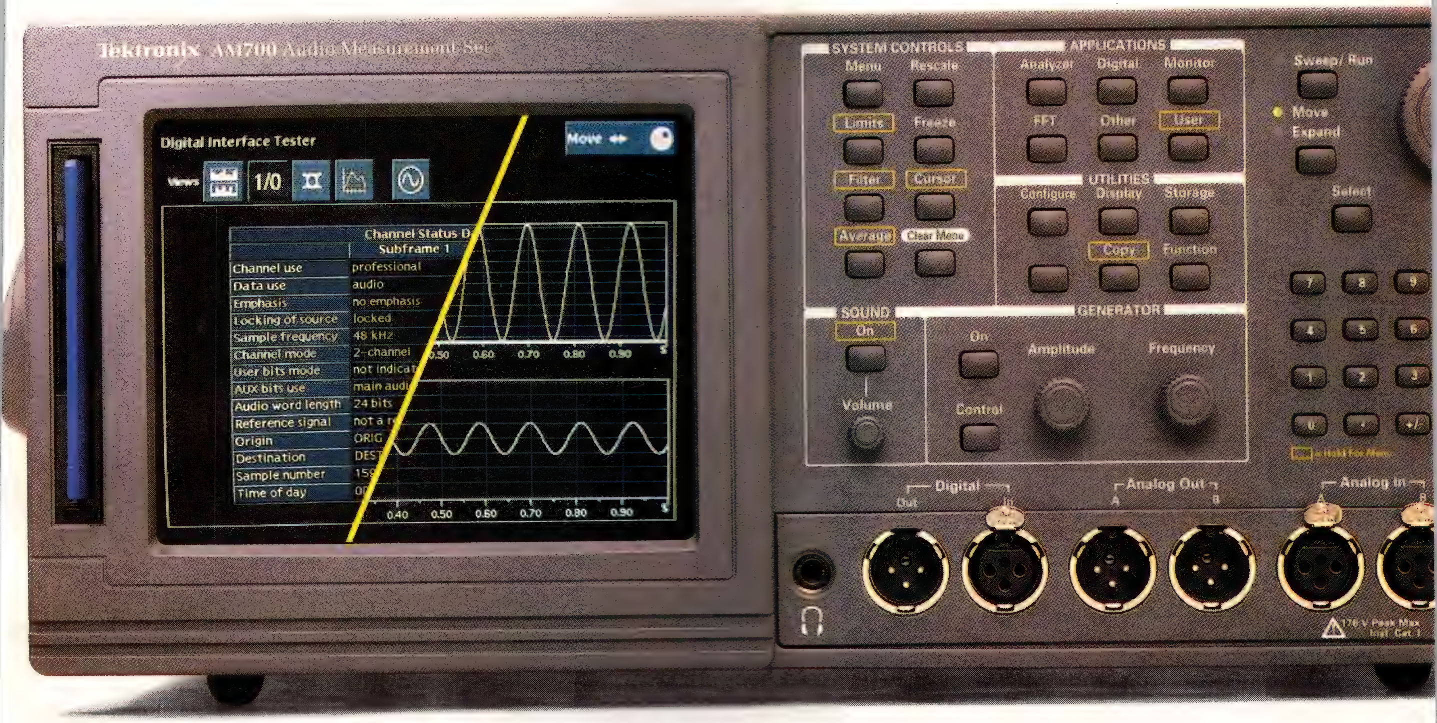
Software-testing tool for DOS adds features. Vermont Test v2.0, formerly Dr Taylor's Test, now has full mouse support, a scripting language, single-step playback enhancements, more record and playback options, and support for additional video modes. The tool test applications in any language. $395. **Vermont Creative Software Inc**, Richford, VT. (802) 848-7731. **Circle No. 32**



Data-acquisition boards have onboard Intel 486 processors. The DAP 3200e family of data-acquisition boards uses onboard 486 microprocessors operating at 24, 48, or 64 MHz to run DAPL, a multitasking real-time operating system. The software and μP enable the boards to run real-time data-acquisition and control applications on a PC, independent of the delays that Windows or other programs running on the PC at the same time impose. The boards have a maximum throughput for the analog section of 2M samples/sec. From $2995. **Microstar Laboratories Inc**, Bellevue, WA. (206) 453-2345. **Circle No. 325**

Mathematical-software tool adds features. Macsyma 2.0 now offers animated object-oriented graphics and a multiple document interface that lets you open multiple notebooks simultaneously. The Matpack module lets you use more than 300 commands to specify and execute linear-algebra operations. Macsyma 2.0 and a companion product, PDEase, provide a tool kit of symbolic and numerical methods for solving partial differential equations. PC Macsyma 2.0 with Matpack is $299. A bundle that includes PC Macsyma 2.0, Matpack, and PDEase costs $749. **Macsyma Inc**, Arlington, MA. (617) 646-4550. **Circle No. 326**

The one audio tester you can use in mixed company.



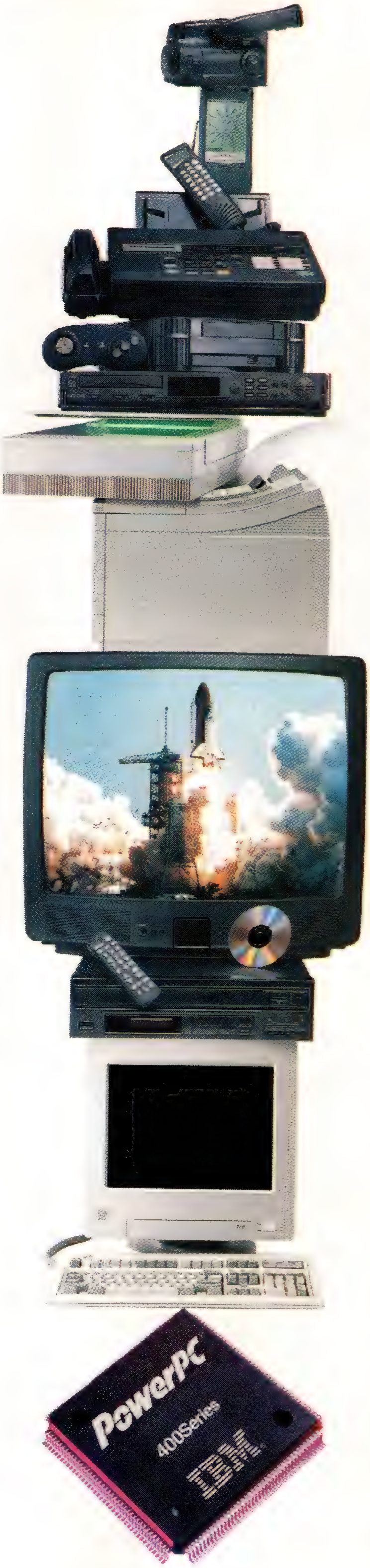
THE TEKTRONIX AM700. THE HIGH PERFORMANCE MIXED SIGNAL AUDIO TESTER THAT'S VERSATILE AND EASY TO USE. ■ Meet a real crowd pleaser. ■ The AM700. It's designed for virtually any audio test application—analog or digital. Making it the perfect choice for testing car radios, recording equipment, radio and television audio broadcast systems, and more. ■ For starters, it's fast and easy to use. There are no complex commands to learn. Just a simple interface that guides you to any function you need. And a high performance processor that gets the job done pronto. ■ Plus, the AM700 lets you work any way you want. Automatically, semi-automatically, or manually. It's ideal for design engineers working at the bench level, test engineers on the production line, and everywhere in between. ■ And it's completely portable, too. Everything's included in one compact instrument. ■ No wonder it knows exactly what to do in mixed company. ■ Make an appointment for a demonstration by calling your local Tektronix sales office or call **1-800-TEK-WIDE ext.TV**

Input and output ports allow you to generate test signals for both analog and digital domains.

Tektronix

CIRCLE NO. 87

IBM and the IBM logo are registered trademarks and PowerPC, PowerPC Architecture, PowerPC Embedded Controllers, PowerPC 601, PowerPC 603, PowerPC 604 and PowerPC Embedded Tools are trademarks of the International Business Machines Corporation. © IBM 1994.



Announcing IBM's PowerPC Embedded Controllers,™ the 400Series. The products you see on this page now share one revolutionary advantage. All can be powered by the advanced PowerPC™ architecture in IBM's new 400Series of embedded controllers.

With the 400Series, now there's a PowerPC solution for your embedded applications, from low-cost consumer electronics all the way to high-performance systems. The first member of IBM's 400Series–our PowerPC 403GA –offers exceptional performance, low power consumption and integrated peripherals at a price that's extremely competitive. Which means you can design low-power systems with fewer components and greater performance. And gain a significant competitive edge in the process.

Of course, successful embedded designs require more than advanced hardware. They need a robust family of support tools. So IBM provides a full range of development tools for embedded customers, including a real-time operating system, compilers, hardware evaluation boards and debug tools. This impressive support level is complemented by IBM's PowerPC Embedded Tools™ Program, which offers a wide selection of tools developed independently by third-party members.

To make your job even simpler, the 400Series is instruction set compatible with IBM's PowerPC 601,™ PowerPC 603,™ PowerP 604™ and higher-level microprocessors. So whenever your application requires compute processing, your investment in tools, training and code development is protected.

To learn more about our new PowerPC 400Series of embedded controllers, call IBM at **1 800 PowerPC**, ext. 1601.

You'll discover the benefits of our PowerPC architecture have become not only accepted, but embedded.

Our PowerPC architecture is now so accepted, it's actually become embedded.

IBM

CIRCLE NO. 37

FREE INFO, FREE POSTAGE

Use our postage-paid reader-service cards to get more information on any of these products.

6-bit embedded controller has 60 bytes of flash memory. The H8/538F microcontroller suits automoive-engine-management and industril-control applications requiring large mounts of flash memory and reprogrammable or uncommitted code storage and programs that need adaptive control algorithms. The second member in the company's Flash-Zero-Turn-Around-Time (F-ZTAT) embedded controllers line, the IC lets you write and rewrite programs even after you mount the device in the product. $40 (10,000). **Hitachi America Ltd, Semiconductor and IC Division**, Brisbane, CA. (800) 285-1601, ext 21. **Circle No. 327**

DSP family offers lower cost version. The ADSP-21062 Super Harvard Architecture Computer (SHARC) DSP is a 2-Mbit version of the previous 4-Mbit ADSP-21060. The 2-Mbit dual-ported SRAM is organized into two banks for dual-operand fetches and independent-core and DMA fetches. The independent I/O processor has 10 DMA channels, two serial ports, each with a throughput of 40 Mbps, and six link or communication ports with a cumulative throughput of 240 Mbytes/sec. All I/O can occur in parallel with the core processing unit as a result of the dual-ported memory. Peak performance on the processor is 120 MFLOPS. $196 (1000). **Analog Devices Inc**, Norwood, MA. (617) 461-3881. **Circle No. 328**

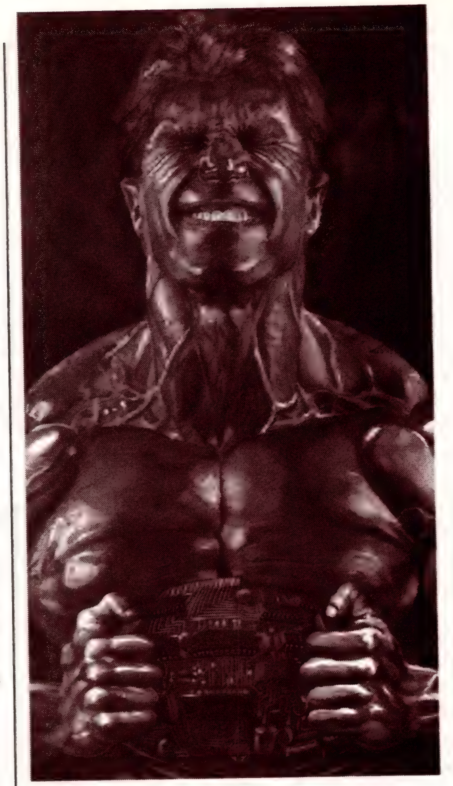
High-speed, low-power RISC-processor core. The VYF86C06-004 ARM6 FSB core is a 32-bit RISC processor that operates at a 45-MHz clock speed. The processor has a peak performance of 45 MIPS and a sustained performance of 38 Dhrystone 2.1 MIPS. Available in a 0.5-µm three-layer-metal CMOS process, the core size is just over 4 mm square and dissipates 110 mW at 3.3V. Price depends on application and the chip in which you use the core. **VLSI Technology Inc**, San Jose, CA. (408) 434-3000. **Circle No. 329**

64-kbyte processor performs broadband-network addressing. The CAM address processor addresses filtering and high-speed search functions for real-time look-up in LAN hubs, bridges, routers, ATM switches, data-service units, switching hubs, and wide-area-network switches. The processor also provides flexible table definitions for networking and internetworking applications and performs programmable input-data formatting. $60 (1000). **Kawasho International, Agent for KLSI Division of Kawasaki Steel**, San Francisco, CA. (415) 391-7242. **Circle No. 330**

SLiC/MP-compatible logic chip set. The 3.3 and 5V Apollo chip sets provide the core logic for the SLiC/MP open-interrupt architecture for multiprocessor desktop computers, including the 64-bit Pentium. The chip set comprises a 208-pin system controller, two 100-pin data buffers that isolate the CPU bus from DRAM and ISA buses, a 160-pin PCI controller, and a 100-pin integrated X-bus peripherals controller. The chip set accommodates up to 512 Mbytes of RAM. From $28 in OEM quantities. **Via Technologies Inc**, Fremont, CA. (510) 683-3300. **Circle No. 331**

Clock-doubled 486 processor runs at 80 MHz. The Am486DX2-80 runs 20% faster than a 66-MHz 486 device. According to the manufacturer, you can upgrade systems using the 40-MHz Am486DX processor by changing the IC, yielding a 70% performance improvement. The processor comes in a 168-pin PGA package and costs $266 (1000). **Advanced Micro Devices Inc**, Sunnyvale, CA. (408) 732-2400. **Circle No. 332**

Symbolic graphical development tools for 32-bit RISC processor run under Windows. The JumpStart 2.1 Windows-based development tools for the ARM RISC processor let you work in a combination of C and assembly language. The tools provide everything to assemble, compile, link, debug, and optimize application software for the processor. The product joins an existing Unix-based product. $3000. **VLSI Technology Inc**, San Jose, CA. (408) 434-3000. **Circle No. 333**



SQUEEZE
More Memory On Your Board

Reduce the size and weight of your design and improve your microprocessor system performance with our new family of high density, high speed memory products.

Our 32-bit wide modules provide you the ultimate in packaging density with our JEDEC Vertical Zip and Simm packages.

Devices are available from stock. Call for samples and application information today.

~ EDI is ISO9001 Certified ~

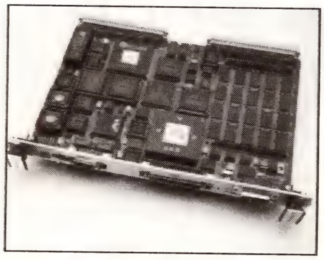
EDI
ELECTRONIC DESIGNS INC.

TEL: **508-366-5151**
One Research Drive
Westborough, MA 01581 USA
FAX: 508-836-4850

Electronic Designs Europe Ltd.
Shelley House, The Avenue Lightwater, Surrey
GU18 5RF United Kingdom
TEL: 0276 472637 FAX: 0276 473748
CIRCLE NO. 33

FREE INFO, FREE POSTAGE
Use our postage-paid reader-service cards to get more information on any of these products.

VMEbus ADC board converts 1.6M samples/sec with 16-bit resolution. The VMIVME-3123 provides 16 differential analog input channels, each with its own fourth-order antialiasing filter, sample-and-hold, and 16-bit A/D converter. Digitized samples are stored in a buffer until the system retrieves them. Software controls buffer size from 1 sample to 4 million samples. The board has an automated self-calibration. $4500. **VME Microsystems International Corp**, Huntsville, AL. (205) 880-0444.
Circle No. 334



VME64 CPU board offers the IDT R4600 or NEC VR4200 CPU. The Laguna CPU board comes with a 100- or 130-MHz R4600 or the 80-MHz VR4200. With the R4600 CPU, the board executes 92 SPECint92 and 82 SPECfp92. The CPU board includes Ethernet and SCSI ports, 2 Mbytes of flash memory, and sockets for up to 256 kbytes of EPROM. Onboard DRAM ranges from 16 to 128 Mbytes. With 16 Mbytes of DRAM, the board costs $6495. **Heurikon Corp**, Madison, WI. (608) 831-5500. **Circle No. 335**

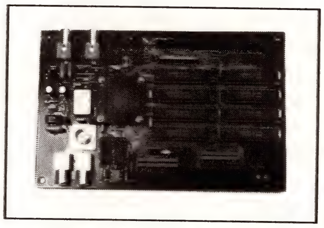
VME module conforms with the CAN standard. The CXM-CAN 3U VME module suits automotive-industry customers who use VME for test automation during manufacturing. The controller-area network (CAN) works as an LAN to measure and control engines, power trains, safety systems, intelligent instruments, and illumination subsystems. CAN provides 1-Mbps data transfer, two-wire communication, and a 50m reach. The CXM-CAN costs $350. **PEP Modular Computers**, Scottsdale, AZ. (602) 483-7100. **Circle No. 336**

In-circuit emulator for Siemens' 80C166 microcontroller family. The ET-iC166 provides full-speed emulation up to 40 MHz without wait states or intrusion on I/O or interrupt pins. You can switch the clock source between the target system and the onboard programmable oscillator. The emulator provides source-level debugging, support for local and global variables, symbolic support for debugging and type checking, and language support for third-party tools. The in-circuit emulator connects to a PC via the com port, printer port, or an optional high-speed, bidirectional, parallel interface. The 40-MHz emulator base unit with 256 kbytes of overlay RAM costs $7200. **Emulation Technology Inc**, Santa Clara, CA. (408) 982-0660.
Circle No. 337

Real-time operating system and set-top box software for PowerPC. OS-9/PowerPC is an optimized version of the company's OS-9 real-time operating system built around the PowerPC architecture. The software takes advantage of PowerPC's architectural features, such as the visual-caching mechanism, which lets you lock time-critical sections of code in the cache. A network-based developer's license costs $7500. **Microware Systems Corp**, Des Moines, IA. (515) 224-1929.
Circle No. 338

Modular vision system processes a 512×512-pixel image in <7.5 msec. The MVC 150/40 Modular Vision Computer is available for either the VMEbus or PC VLbus systems. The basic system has a 40-MHz pipelined processing architecture with up to 15 optional modules that add or expand acquisition, processing, or I/O capabilities. From $7500 in OEM quantities. **Imaging Technology Inc**, Bedford, MA. (617) 275-2700. **Circle No. 339**

Fuzzy-logic and neural-network development tool generates ANSI-standard C code. The NeuFuz4-C Windows-based fuzzy-logic development tool lets you develop applications for any embedded processor served by a C compiler. According to the company, the tool combines the strongest elements of fuzzy logic with learning and generalization capabilities of neural networks to develop embedded-control applications. The full software costs $15,000. A learning version costs $399. **National Semiconductor Corp**, Santa Clara, CA. (800) 272-9959.
Circle No. 340

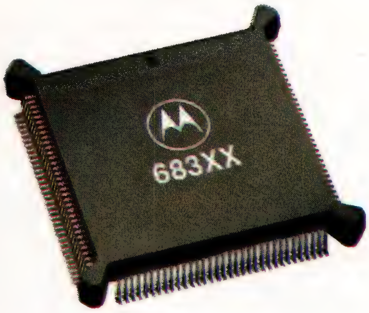


Speech-processing development system is based on the Motorola DSP-56166 16-bit fixed-point DSP. The DSP56166 development system connects to any computer with an RS-232C interface. The unit has up to 64k words of program memory, 64k words of data memory, a 14-bit sigma-delta voice band codec, and audio I/O jacks. A second product, the CC-561xx converts RS-232C commands from the controlling computer to a format compatible with the Motorola OnCE interface for on-chip emul tion. The unit provides emu lation for prototype proc ucts containing th DSP56166. The DSP-5616 costs $695, and the CC 561xx costs $335. **The Acco lade Group Ltd**, Highlan Park, IL. (708) 831-3009.
Circle No. 34

Development system and programmer fo stand-alone fuzzy-logi controllers. You can develop fuzzy-logic applicatio programs for the company' stand-alone fuzzy-logic controllers using Insight, a Windows-based developmen system. The developmen system lets you define al membership functions and simulate the system. The Instant programmer is used to download, verify, or erase a device. Insight and Instant cost $995 each or $1595 for both. **Neuralogix**, San Jose, CA. (408) 383-7200.
Circle No. 342

Ada integrated-development environment for Windows. ActivAda for Windows includes an optimizing compiler that generates code for both DOS and Windows, taking full advantage of the underlying system architecture. The software performs full 32-bit code generation. ActivAda for Windows costs $995. AdaWorld for DOS is $595, and AdaWorld for 386/Unix and 386/Solaris are now $2995 each. **Alsys Inc**, San Diego, CA. (619) 457-2700.
Circle No. 343

Motorola 68341 processor. The T3000 is a computer intended for real-time embedded applications and includes an ANSI-standard C compiler and development tools. Onboard flash memory and battery-backed static memories allow field upgrades over a serial port. The computer accommodates up to 64 Mbytes of DRAM and has four high-speed serial



You're choosing a Motorola® 683XX for its high degree of integration, superior real-time performance and low cost.

Choose OS-9® system software for the same reasons.

The OS-9 Real-Time Operating System is a perfect software match for Motorola's 683XX family of integrated processors. Each member of the 683XX family can be coupled with a specific, optimized OS-9 microkernel assuring you matching performance. OS-9's modular I/O system complements the I/O on your 683XX, including full support of the 68360 Quad Integrated Communication Controller. This allows seamless integration into any application such as telecommunications, automotive, consumer electronics or industrial automation.

To get your software development up quickly and to produce the tightest 683XX application code, Microware provides FasTrak productivity tools built around Ultra C. The Ultra C ANSI C compiler features modes targeting the 68000 and CPU32 cores for highly optimized applications. And Ultra C's ability to link prior to optimization introduces true global and interprocedural optimization into your code.

OS-9 also offers cost-effective software licensing with no per-project development fees. And OS-9's modularity lets you ship only the software you need for your product.

Get the real-time operating system that matches your 683XX. Get OS-9. Call 1-800-475-9000 today for more information.

microware®

OS-9 makes it simple.™

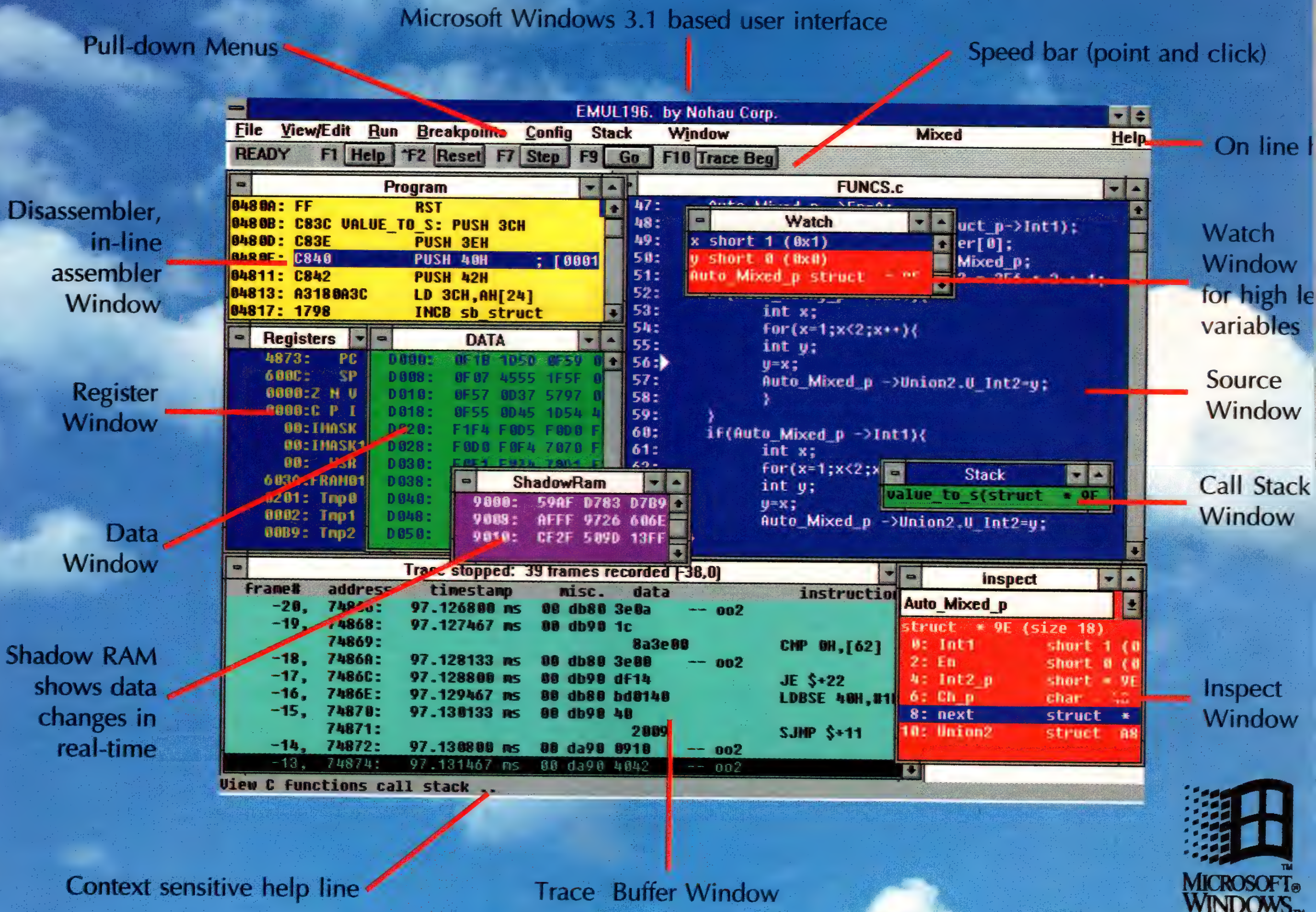
Microware Systems Corporation • 1900 N.W. 114th Street • Des Moines, Iowa 50325-7077 • Phone: (515) 224-1929 • Fax: (515) 224-1352 • Internet: info@microware.com

Microware and OS-9 are registered trademarks of Microware Systems Corporation. Ultra C and FasTrak are trademarks of Microware. Motorola and Ⓜ are registered trademarks of Motorola, Inc.

CIRCLE NO. 97

80C196

In-Circuit Emulators


Microsoft Windows 3.1 based user interface
Pull-down Menus
Speed bar (point and click)
On line H
Disassembler, in-line assembler Window
Watch Window for high le variables
Register Window
Source Window
Data Window
Call Stack Window
Shadow RAM shows data changes in real-time
Inspect Window
Context sensitive help line
Trace Buffer Window
EMUL196. by Nohau Corp.
File View/Edit Run Breakpoints Config Stack Window Mixed Help
READY F1 Help ^F2 Reset F7 Step F9 Go F10 Trace Beg
Program
Registers
DATA
ShadowRam
FUNCS.c
Watch
Stack
Inspect

```
0480A: FF                RST
0480B: C83C VALUE_TO_S:  PUSH 3CH
0480D: C83E              PUSH 3EH
0480F: C840              PUSH 40H        ; [0001
04811: C842              PUSH 42H
04813: A3180A3C          LD 3CH,AH[24]
04817: 1798              INCB sb_struct
```

```
4873:    PC
600C:    SP
0000:Z N V
0000:C P I
  00:IMASK
  00:IMASK1
  00:   WSR
6030:FRAM01
0201: Tmp0
0002: Tmp1
00B9: Tmp2
```

```
D000:  0F1B 1D50 0F59 0
D008:  0F07 4555 1F5F 0
D010:  0F57 0D37 5797 0
D018:  0F55 0D45 1D54 4
D020:  F1F4 F0D5 F0D0 F
D028:  F0D0 F0F4 7070 F
D030:
D038:
D040:
D048:
D050:
```

```
9000:  59AF D783 D7B9
9008:  AFFF 9726 606E
9010:  CF2F 509D 13FF
```

```
x short 1 (0x1)
y short 0 (0x0)
Auto_Mixed_p struct
```

```
48:                  uct_p->Int1);
49:                  er[0];
50:                  Mixed_p;
53:         int x;
54:         for(x=1;x<2;x++){
55:         int y;
56:         y=x;
57:         Auto_Mixed_p ->Union2.U_Int2=y;
58:         }
59:     }
60:     if(Auto_Mixed_p ->Int1){
61:         int x;
            for(x=1;x<2;x
            int y;
            y=x;
            Auto_Mixed_p ->Union2.U_Int2=y;
```

```
value_to_s(struct  * 9F
```

```
Trace stopped:  39 frames recorded [-38,0]
 Frame#  address   timestamp     misc.    data          instruction
  -20,   74866:   97.126800 ms  00 db80 3e0a    -- oo2
  -19,   74868:   97.127467 ms  00 db90 1c
         74869:                          8a3e00         CMP  0H,[62]
  -18,   7486A:   97.128133 ms  00 db80 3e00    -- oo2
  -17,   7486C:   97.128800 ms  00 db90 df14            JE $+22
  -16,   7486E:   97.129467 ms  00 db80 bd0140          LDBSE 40H,#1
  -15,   74870:   97.130133 ms  00 db90 40
         74871:                          2009           SJMP $+11
  -14,   74872:   97.130800 ms  00 da90 0910    -- oo2
  -13,   74874:   97.131467 ms  00 da90 4042    -- oo2
View C functions call stack ..
```

```
Auto_Mixed_p
struct   * 9E (size 18)
 0: Int1           short 1 (0
 2: En             short 0 (0
 4: Int2_p         short * 9E
 6: Ch_p           char
 8: next           struct  *
10: Union2         struct  A8
```

MICROSOFT® WINDOWS™ COMPATIBLE

FEATURES:

- Support for 80C196: KR/Q/T/C/D, JR/Q, NQ/T & more.
- Real-time emulation at maximum chip speeds.
- Use of bond-out chips for accurate emulation.
- Hosted on PC's and workstations.
- High Level support for popular C-compilers.
- Unlimited hardware breakpoints.
- Break in real-time on Internal Access, both on data value and address.
- Trace board up to 512K deep, 104 bits wide, with 40 bit timestamp. Triggering and filtering with full instruction queue decoding.
- Memory contents shown during real-time emulation (Shadow RAM).
- Code Coverage and Program Performance Analysis.
- CCB's controlled from user interface. (Wait states, timing mode, bus width and more.)

Also supported:

8051 68HC11
68HC16 683xx

To learn more, *please call (408) 866-1820 for a FRE Demo Disk. For more information via your Fax, call ou 24-hour Information Center at (408) 378-2912.*

NOHAU
CORPORATION

51 E. Campbell Avenue
Campbell, CA 95008-205
Fax. (408) 378-7869
Tel. (408) 866-1820

Argentina 1 312-1079, Australia (02) 654 1873, Austria 0277 20-0, Benelux (01858) 161
Brazil (011)-458-8755, Canada 1-514-689-5889, Czechoslovakia 0202-2683, Denmark 43
60 10, Finland 90-4526-21, France (1) 69 41 28 01, Germany 49-7043-40247, Great Bri
0962-733140, Greece 1-924 20 72, India (0212) 422164, Israel (03) 491202, Italy (0
437 15 51, Korea (02) 784-7841, New Zealand 09-3092464, Norway 22-67 40
Portugal 01-80 95 18, Romania 961-30078, Singapore 749-0870, S. Africa (021) 23-49
Spain (93) 276 22 69, Sweden 040-92 24 25, Switzerland 01-740 41 05, Taiwan 02 76402
Thailand (02) 281-9596.

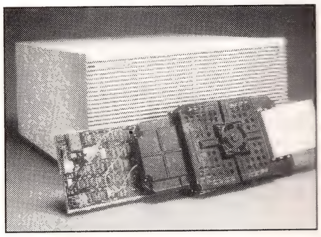
CIRCLE NO. 69

ports and a 2.5-Mbps Arcnet nterface for twisted pairs. The unit includes a 200-Mbyte disk drive and is housed in a weather-resistant 9×12×4-in. package. A full development system and computer cost $3950. The T3000 alone starts at $999. **Tuple Inc**, Issaquah, WA. (206) 746-3935.

Circle No. 344

ISA bus single-board computer increases video throughput with local-bus video. The LB486SLC passive-backplane single-board computer has up to 4× the performance of other systems that rely on the ISA bus to transmit video data. The board includes a 128-kbyte cache, a 16-Mbyte onboard DRAM, two serial ports, a parallel port, an IDE-disk interface, a floppy-disk interface, a real-time clock, and a watchdog timer. $836 in OEM quantities. **I-Bus Division of Maxwell Laboratories**, San Diego, CA. (619) 569-0646.

Circle No. 345



Emulator for the 80386 supports all addressing modes. The HP 64789A provides real-time, zero-wait-state emulation to 33 MHz. A special bond-out version of the µP lets the emulator support all addressing modes. The emulation system uses an 80-channel bus analyzer for selective, nonintrusive analysis of target-system activity. Trace buffers are available in 8-, 64-, and 256k-deep configurations. The emulator can accommodate up to 8 Mbytes of emulation memory. $26,500. **Hewlett-Packard Co**, Santa Clara, CA. (800) 452-4844.

Circle No. 346

Real-time operating system is binary-compatible with UNIX. Venix EDS, a real-time operating system for embedded systems, is binary-compatible with UnixWare from Novell. According to the company, the operating system offers the benefits of a standard operating system, including third-party compatibility with embedded and real-time capabilities. A complete development system is $14,000. **VenturCom Inc**, Cambridge, MA. (617) 661-1230. **Circle No. 347**

Real-time embedded-development system for Windows supports 68000 CPU boards. The PDOS Windows development environment provides the multitasking PDOS 4.2 real-time operating system, a source-level Windows cross-debugger, a Windows text editor, and the PXNET networking package that supports TCP/IP streams and UDP data grams. $2500. **Eyring Corp**, Midvale, UT. (801) 561-1111.

Circle No. 348

VMEbus DSP board performs a 1k complex FFT in 106 µsec. The UltraDSP uses the Sharp LH9124, a 24-bit floating-point DSP, for calculations and the AT&T DSP-32C for supervision and programming. Achieving 400-MIPS performance, the board can implement FIR filters with 12.5 nsec per tap. The board performs up to 128k complex and 256k real FFTs. $22,000. **Valley Technologies**, Tamaqua, PA. (717)668-3737. **Circle No. 349**

DIGITAL SIGNAL PROCESSING
DATA ACQUISITION
SIGNAL ANALYSIS

If you need solutions to real-world problems in

- Multichannel spectrum analysis
- Real-time image processing
- Noise and vibration analysis
- On-line monitoring
- Process control
- Acoustics
- Digital audio
- Sonar or radar

contact the DSP experts at Pentek.
You'll be glad you did.

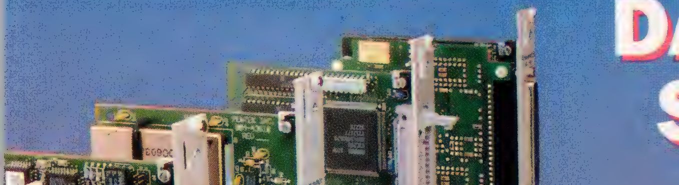
When it comes to DSP...
Pentek has the whole solution

PENTEK — *Innovative DSP systems*

55 Walnut Street ◆ Norwood, NJ 07648 ◆ Tel: 201-767-7100 ◆ Fax: 201-767-3994 ◆ BBS: 201-767-8733

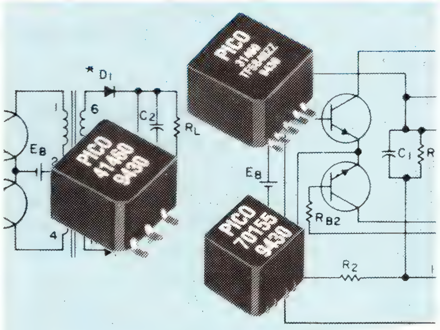
CIRCLE NO. 77

© 1994 Pentek, Inc.



PICO

ULTRA-MINIATURE
SURFACE MOUNT
Transformers
& Inductors



Gull Wing / J Lead

These units have gull wing construction which is compatible with tube fed automatic placement equipment or pick and place manufacturing techniques. Transformers can be used for self-saturating or linear switching applications. The Inductors are ideal for noise, spike and power filtering applications in Power Supplies, DC-DC Converters and Switching Regulators.

- *Operation over ambient temperature range from −55°C to +105°C*
- *All units are magnetically shielded*
- *All units exceed the requirements of MIL-T-27 (+130°C)*
- *Transformers have input voltages of 5V, 12V, 24V and 48V. Output voltages to 300V.*
- *Transformers can be used for self-saturating or linear switching applications*
- *Schematics and parts list provided with transformers*
- *Inductors to 20mH with DC currents to 23 amps*
- *Inductors have split windings*

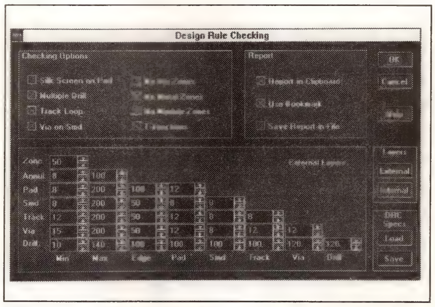
Delivery—stock to one week

See EEM
or send direct
*for **Free** PICO Catalog.*
*Call toll free **800-431-1064***
*in NY call **914-699-5514***
*FAX **914-699-5565***

PICO Electronics, Inc.
453 N. MacQuesten Pkwy., Mt. Vernon, N.Y. 10552
CIRCLE NO. 79

FREE INFO, FREE POSTAGE
Use our postage-paid reader-service cards to get more information on any of these products.

RF-conversion software runs under Windows. TxRx Designer ($149) is an RF-conversion system feasibility-analysis tool. The tool provides a 3-D view of frequencies and cascade parameters and a graphical spur-web method of mixer spurious-product evaluation to simplify analysis. The software performs dynamic range, filter-noise bandwidth, local oscillator and input-power leakage to the output, and spur-power calculations. **Waypoint Software**, Waseca, MN. (507) 835-7429. **Circle No. 366**



Windows-based pc-board design tool upgraded with advanced-DRC and edit features. WinBoard version 1.10 has an advanced design-rule-check (DRC) capability to test the annular-ring width of pads and vias. The DRC also examines spacing check on drill holes, track loops, vias on SMD pads, and silk-screen overlap on SMD pads. A global-edit capability lets you select and edit objects such as pads, tracks, vias, text, and copper zones. The tool allows you to create and edit netlists as you design the pc board and preview the design before you print. $995. **Ivex Design International**, Beaverton, OR. (503) 531-3555. **Circle No. 367**

Graphical framework and viewer provide efficient signal-integrity analysis environment. The PCB-Route Evaluation and Control-Interface-System Environment (PRECISE) is a pc-board and MCM layout viewer with a graphical user interface for the company's signal-integrity tools. The viewer lets you examine the physical layout and graphically select portions of the design for analysis. When used in combination with the company's other tools, you can explore different driver, receiver, and termination options and perform other signal-integrity-relate trade-offs. From $7000. **Quad Design**, Camarillo, CA. (805) 988-8250. **Circle No. 36**

Database service integrates multi source data with CAD/CAE data and document management. The Congruity integrated information solutions product has search, retrieval, image-viewing, and system-administration software integrated with your choice of the company's databases. The product's customizable architecture lets you search, view, and manipulate data directly from a variety of integrated desktop applications. A basic 20-user subscription costs less than $50,000. **Information Handling Services**, Englewood, CO. (303) 790-0600. **Circle No. 369**

ASIC design software suits designs down to 0.35 μm. OpenCAD Version 4 is a front- to back-end design package for designers using the company's ASIC foundry service. The tool provides special features such as floorplanning, clock tree synthesis, and automatic-test-pattern generation. The new version also includes resistance and capacitance extraction techniques for accurate delay calculations of submicron designs. The software is part of the company's normal ASIC NRE charge. **NEC Electronics Inc**, Mountain View, CA. (415) 965-6000. **Circle No. 370**

Software-simulation model for the PowerPC 603 microprocessor. The Logic Modeling Group of Synopsys and IBM has agreed to use design data in the form of behavioral models to create, distribute, and support high-performance software-simulation models for system design. The first model developed under this program is for the PowerPC 603 and is included in the SmartModel Library. From $12,900. **Synopsys Inc**, Beaverton, OR. (800) 344-0004. **Circle No. 371**

Analog and mixed-signal design software available for the Power Macintosh. ICAP/4Power Macintosh is a native version of the company's ICAP/4 CAE tool for Power Macintosh computers. The tool provides an integrated schematic-entry program and an analog and mixed-signal simulator based on Berkeley Spice 3F.2 with graphical-waveform processing. The software simulates mixed analog and digital circuits, pc-board transmission

AMCC PCI Controllers: The Fastest Way To Hook Onto The Bus

Are compliance issues keeping you off the PCI Bus? Then call AMCC and start reeling in the highest performance from your design. Our new S593X PCI Matchmaker controllers are just the ticket to hook onto the Local Bus. And our interface devices are fully compliant with Rev. 2.0 of the PCI specification. Are yours?

Whether your application requires a simple "target" or a flexible "bus master", AMCC will show you the most affordable route to your interface solution.

The Easiest Way To "Plug and Play"

The S593X controllers provide a flexible, general purpose interface that easily connects most add-on applications to the Local Bus.

SAMPLING NOW!

Designing LAN/Networking adapter cards, data acquisition modules or multimedia peripherals? Reach your design destination faster with AMCC Matchmaker controllers.

The Bus Stops Here

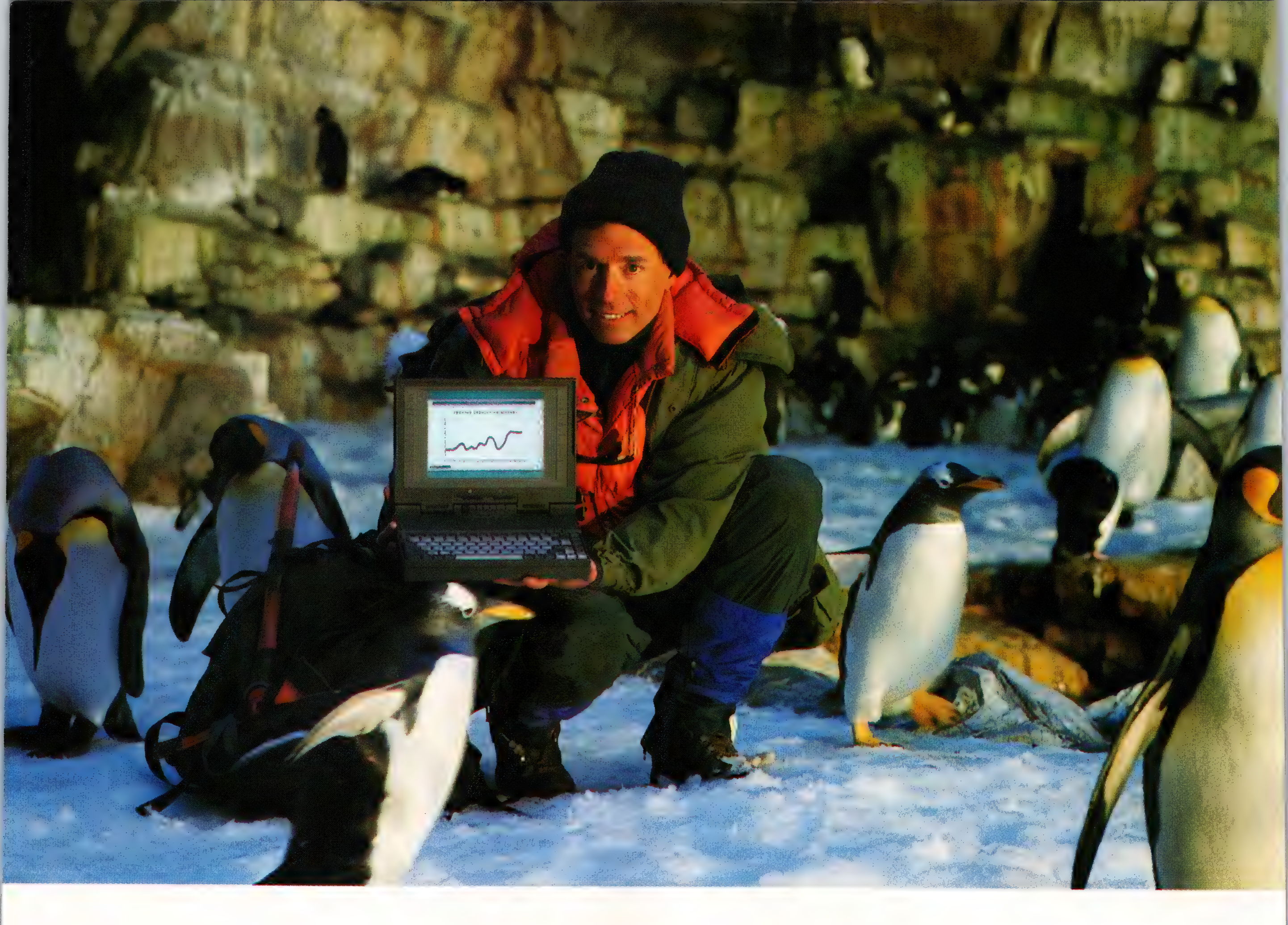
Don't let your design stall. Call us now and ask for your copy of our PCI Matchmaker Controller databook. We won't let you miss the Bus. Or fax us at (619) 450-9885.

AMCC

Call 800-755-2622

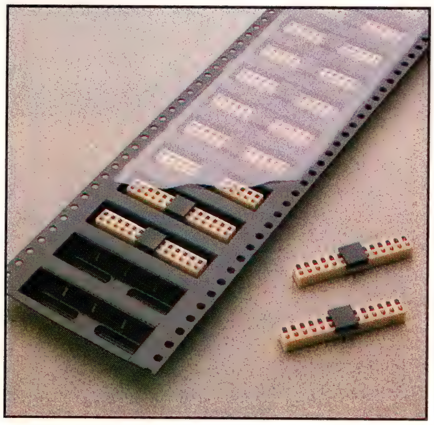
See A Demo of the PCI Controller at Fall COMDEX, Booth S4089 in the Las Vegas Convention Center

CIRCLE NO. 91



If you were 4,000 miles from spare parts, what 2mm connector would you spec?

For 2mm, trust 3M. Now available in convenient tape-and-reel packaging.



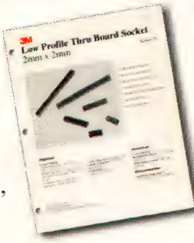
When it comes to reliability, 3M's 2mm connectors are second to none. They're tough enough to withstand the high-temp rigors of infrared and vapor phase soldering — without warping or blistering. They're compatible with vacuum pick-and-place equipment, providing precise placement every time. And, they possess the same 3M quality construction and durability that hallmarks every one of our products.

All of which means that they'll provide years of trouble-free service to the people who depend on your products day and night, even if that night lasts for months at a time.

Of course, those same qualities also mean you'll enjoy fewer manufacturing problems, especially when you take advantage of our tape-and-reel packaging.

3M offers a full line of 2mm connectors, as well as custom engineering support. No matter what you need, we can build it. In fact, you could go to the ends of the Earth and not find a better, more reliable connector, or a more responsive supplier.

So, if failure leaves you cold, call 1-800-354-1919 and we'll send you more information on some of the hottest 2mm connectors around. 3M Electronic Products Division, 6801 River Place Boulevard, Austin, Texas, 78726-9000.

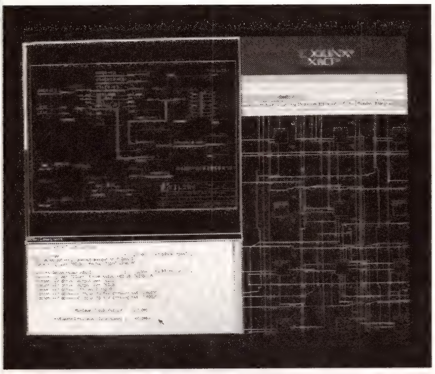


© 3M 1994
Copyright © 1994, Sea World, Inc. All rights reserved. Reproduced by permission.

CIRCLE NO. 2

3M *Reliability*

lines, and mixed-domain systems such as mechanical and electrical. $1725. **Intusoft**, San Pedro, CA. (310) 833-0710. **Circle No. 372**



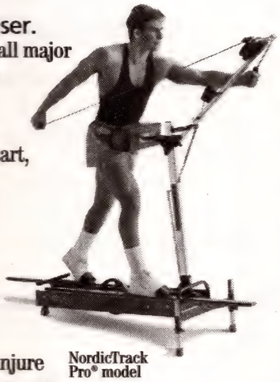
Programmable-logic design software adds features. The XACT 5.0 design software for the company's FPGA and EPLD products has time-saving features. Designers of SC3000 and 4000 family products can save time using the incremental-design capability and freezing parts of a design that don't need to change. The software provides timing-driven routing for those families. A unified library lets you create a design and then automatically try over 45 devices without additional design work. EPLD design features include automatic PAL conversion. From $995 on PCs and $7995 on workstations. **Xilinx Inc**, San Jose, CA. (408) 559-7778. **Circle No. 373**

SHORTS

Release 8.0 of the Allegro Correct-by-Design System is now shipping. The pc-board design tool lets you program design flows with customization to automate the steps in creating a physical design. From $33,000 to $109,000, depending on configuration. **Cadence Design Systems Inc**, (408) 943-1234. **Circle No. 374**

The BooleDozer logic-synthesis tool now accepts Verilog HDL **Altium Inc**, (408) 534-4100. **Circle No. 375**

Epoch/Datapath automates the layout of deep-submicron data-path designs. $80,000. **Cascade Design Automation**, (206) 643-0200. **Circle No. 376**



What does it take to be "The World's Best Aerobic Exerciser®"?

It takes a total-body exerciser.
A machine capable of exercising all major muscle groups, not just your legs.

It takes a cardiovascular exerciser.
A machine that exercises your heart, not just specific muscle groups.

It takes a calorie-burning exerciser.
A machine that can burn up to 1,100 calories per hour.

It takes a safe exerciser.
A machine that can't damage your knees like stairsteppers, or injure your back like hydraulic-cylinder rowers.

It takes an exerciser you'll use.
Recent independent studies show that after five years, 7 out of 10 owners use their NordicTrack® exerciser an average of three times a week.

NordicTrack Pro® model

- Independently Adjustable Upper-Body Exerciser
- Electronic Feedback
- Stand-Up Position
- Independently Adjustable Lower-Body Exerciser
- Non-Jarring Motion
- Adjustable Elevation
- Patented Flywheel and One-Way Clutch Mechanism
- 30-Day In-Home Trial

It takes a NordicTrack.

NordicTrack
A CML Company

©1994 NordicTrack, Inc., A CML Company • All rights reserved.

FREE VIDEO & BROCHURE
CALL: 1-800-441-7891
Ext. 13LJ4

☐ Please send me a FREE brochure
☐ Also a FREE VHS videotape
Name ______ Phone ( ) ______
Street ______
City ______ State ______ Zip ______
Call or send to: NordicTrack, Dept. 13LJ4
104 Peavey Road, Chaska, MN 55318-2355

CIRCLE NO. 123

Trimmers Anyone?...

Piher International Corp. has a trimmer to satisfy your needs, regardless of application. For example, our new 6 mm trimmers: the cost efficient N6 Series for automatic insertion use and the cermet PJ6/PS6 Series for use where size is critical.

Consider our enclosed 10mm or 15mm carbon PT Series, or their cermet track counterparts, the PTC Series which offers 86 different adjustment and mounting combinations. And, Piher offers a large selection of shafts and thumb wheels to suit any requirements.

Contact us for samples, quotations, product literature or more detailed information. As the most widely used trimmers in the U.S., you'll see how Piher beats the competition...hands down.

ISO 9001
REG. 08/100/9037/3

PIHER
INTERNATIONAL CORP.
MEGGITT ELECTRONICS

903 Feehanville Drive
Mt. Prospect, IL 60056
Telephone: 708/390-6680
Toll-Free: 800/323-6693
Facsimile: 708/390-9866

CIRCLE NO. 80

DC/DC converters are 24-pin-DIP compatible. The 2W 200MFR2 and 3W 300MFR2 modules offer single and dual outputs of 5, 12, 15, ±12, or ±15V. Inputs are 5, 12, 24, or 48V. Line- and -load regulation is 0.5%; input-to-output isolation is 500V. Cooled by free-air convection, the converters maintain full rated power from –25 to +71°C. Prices for the 1.25×0.8×0.4-in. converters start at $12.60 (100). **Conversion Devices Inc**, Brockton, MA. (508) 559-0880. **Circle No. 350**

FREE INFO, FREE POSTAGE
Use our postage-paid reader-service cards to get more information on any of these products.

Power-factor-corrected, 600W supply has four outputs. The J-604 supply features 0.995 power-factor correction and delivers a maximum of 120A or 600W from the main output and a combined maximum of 440W from the auxiliaries. Output voltages of 2 to 48V dc are available for main output, and voltages of 2 to 24V dc are available for auxiliaries. You can configure Model J-601 with a 380V-dc output for distributed-power applications. All models have a universal ac-input range of 90 to 264V ac, 47 to 63 Hz, single phase. Prices for single-output models start at $645 (25), and prices for four-output models start at $795 (25). **Jeta Power Systems Inc**, Signal Hill, CA. (310) 427-0095. **Circle No. 351**

All Things Considered:
Battery Selection, Made In USA, Tech Support, Order Flexibility, Customer Service Response, & Battery Performance

You Can't Buy A Better Battery Than Carefree

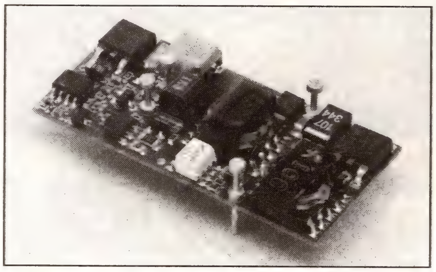
At Eagle-Picher, we feature the Carefree Maintenance-Free Rechargeable Battery series for long-life, ease of use and the efficiency of lead-acid power supplies.

Next time you need a reliable, cost-effective, rechargeable power source, count on Eagle-Picher.

WINNER!
Bell Canada Award of Excellence for Outstanding Suppliers.
Supplier to the winner of Sunrayce 1993.

EAGLE EP PICHER
COMMERCIAL PRODUCTS DEPARTMENT
Post Office Box 130 • Seneca, Missouri 64865
Phone: 417-776-2256 • FAX: 417-776-2257

CIRCLE NO. 31



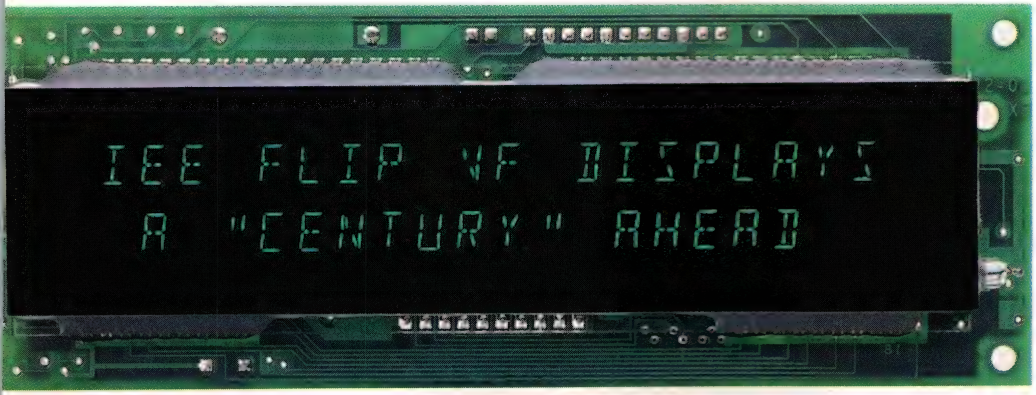
DC/DC converter has 10W output power from a 1×2×0.375-in. package. The BX10 series converters accept input voltages of either 18 to 75 or 9 to 36V dc and provide regulated single and dual output voltages of 2.1, 3.3, 5, 12, 15, ±5, ±12, and ±15V. Peak efficiencies range from 79 to 88%. Single-piece prices start at <$50. **Computer Products Inc**, South Boston, MA. (617) 268-1170. **Circle No. 352**

Low-profile 600W inverter handles surges to 1500W. The PSE-1260 modified sine-wave inverter measures 11×7.9×2.8 in. and weighs 5 lbs. The inverter has electronic protection on the output, low-battery alarm and shutdown, LED displays for voltage, current, over-temperature, and overload conditions. Available with either 12- or 24V-dc input, the inverter costs $450(CN). **Absopulse Electronics Ltd**, Carp, ON, Canada. (613) 836-3511. **Circle No. 353**

DC/DC converter modules target disk drives and other mass-storage devices. Diskpower converter modules operate over an input voltage range of 18 to 36V or 36 to 72V. The converters provide separately regulated 5 and 12V outputs with overvoltage and current protection. The 12V output accommodates peak spin-up surges of 3.5A (50-series) and 5A (70-series). TC050AB, $35 (OEM qty); TC070AB, $50. **AT&T Microelectronics**, Allentown, PA. (800) 372-2447. **Circle No. 354**

The FLIP *Century*™ Series

A New Era in VF Displays



03702-020-05220

Key Features

- Interface to Intel or Motorola host processors.
- Emulate Hitachi 44780 data input.†
- Parallel 8-bit or serial EIA-232 data to 19.2Kb.
- Low 5Vdc power.
- 100% surface mount technology.
- Standard temperature range -20° to +70°C. Extended range available -40° to +85°C.
- Hardware and software self-test modes.

(Displays Shown Actual Size)

Software Control Features

- Selectable character sets: ASCII, European, Katakana, Cyrillic and Hebrew.†
- Segmented displays have standard ASCII 64-character set.
- Ten (10) user-defined, downloadable characters.†
- Vertical and horizontal scroll modes.
- Eight (8) software and hardware controlled dimming levels.
- Variable blink fields and rates.
- Screen saver control mode for increased tube life.
- Bell alarm output.†

† Dot matrix units only

IEE is a sustaining member of SID

03602-100-05420

Versatile, Compact, High-Performance...Value Priced!

Model	Character Format	Display Format	Character Height	Package Size: Length	Package Size: Width	Package Size: Depth	Max. Current
03602-100-05420	5x7 dot matrix	4x20	5mm	5.00″	2.78″	0.92″	890mA
03602-105-05220	5x7 dot matrix	2x20	5mm	5.00″	2.25″	0.88″	405mA
03602-122-09220	5x7 dot matrix	2x20	9mm	7.75″	2.58″	1.00″	675mA
03602-124-09420	5x7 dot matrix	4x20	9mm	7.75″	3.40″	1.00″	1300mA
03702-020-05220	14-segment	2x20	5mm	5.65″	1.98″	0.82″	270mA
03702-021-08110	14-segment	1x10	8mm	5.00″	1.60″	0.90″	140mA
03702-022-13112	14-segment	1x12	13mm	7.20″	2.40″	0.90″	323mA
03702-024-09116	14-segment	1x16	9mm	6.70″	2.30″	0.90″	360mA
03702-026-09120	14-segment	1x20	9mm	8.30″	2.35″	0.95″	390mA
03702-029-13120	14-segment	1x20	13mm	10.20″	1.93″	0.96″	526mA

IEE®
DISPLAYS
KEYBOARDS
INTEGRATED PANELS

INDUSTRIAL ELECTRONIC ENGINEERS, INC.
7740 Lemona Avenue
Van Nuys, California 91409-9234
Tel 818-787-0311 ext. 418 • Fax 818-901-9046

Immediate Response Circle 117
Reference Only Circle 118

FREE INFO, FREE POSTAGE
Use our postage-paid reader-service cards to get more information on any of these products.

Wireless LAN adapter has 1.6-Mbps data rate over 15 independent channels. The RangeLAN2/PCMCIA local-area network (LAN) adapter uses frequency-hopping spread-spectrum techniques in the 2.4-GHz frequency band. The adapter fits in a PCMCIA Type II card slot and is compatible with Card and Socket Services 2.1. Range is 500 ft in office environments and 1000 ft in open areas. The RangeLAN2/PCMCIA costs $695, and an ISA bus version costs $595. **Proxim Inc**, Mountain View, CA. (415) 960-1630. **Circle No. 355**

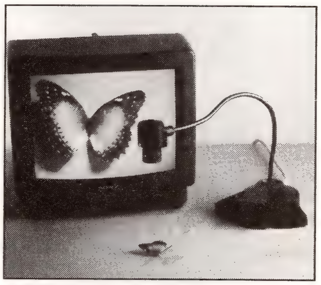
PCMCIA memory cards offer up to 10 Mbtyes of nonvolatile storage. The QCard family of memory cards offer 1, 2, 4, and 10 Mbytes of storage on PCMCIA Type I and II cards. Driver software is resident on the card, eliminating the need to load card-specific software via floppy disk. The cards use 512-byte blocks that save power and improve performance when erasing or rewriting data. Write endurance is a minimum of one million cycles. Single unit prices range from $90 for 1 Mbyte to $520 for 10 Mbytes. **Quantum Corp**, Milpitas, CA. (408) 894-4000. **Circle No. 356**

Industrial computers use Pentium processor. The IRC870 and IRC872 industrial computers have positive pressure cooling for operation to 50°C. A shock-mounted drive bay helps protect hard-disk, floppy-disk, and CD-ROM drives. The IRC870 features a 60-MHz Pentium microprocessor with 8 Mbytes of DRAM, a 340-Mbyte hard disk, and a PCI-video accelerator with 1 Mbyte of DRAM and starts at $3095. The IRC872 features a 90-MHz Pentium microprocessor with 16 Mbytes of DRAM, a 340-Mbyte hard disk, SCSI dual speed CD-ROM, and a PCI-video accelerator with 2 Mbytes of DRAM and starts at $4495. **Nortech Engineering Inc**, Medfield, MA. (508) 359-6063. **Circle No. 357**

Audio adapter for PCs features ISO/MPEG-1 compression and direct-to-disk 16-bit stereo. The Series 2/Model SX-33 audio adapter uses the TMS320-C31 floating-point DSP to provide direct-to-disk recording and playback with a frequency response of 20 Hz to 20 kHz. In addition to the ISO/MPEG-1 compression technology with compression ratios of up to 16:1, the board supports other compression formats including OKI ADPCM, Microsoft ADPCM, DVI ADPCM, CDI ADPCM, CD-ROM, XA ADPCM, and 8- and 16-bit PCM. The SX-33 digital audio processor costs $595, and an audio developers kit costs $750. **Antex Electronics Corp**, Gardena, CA. (310) 532-3092. **Circle No. 358**

Portable workstation offers active-matrix LCD. The SPARCstation Voyager is a 13-lb system available with a 14-in. monochrome active-matrix LCD ($9995), a 12-in. color active-matrix LCD ($14,995), or a 17-in. traditional-color CRT ($8995). The systems use a microSPARC II CPU running at 60 MHz to deliver 43SPECint92 and 37SPEC-fp92 performance. Main-memory capacity is 16 to 80 Mbytes. The system also has a 340-Mbyte hard drive, a 3.5-in. floppy drive, two PCMCIA card slots, and an IR interface. **Sun Microsystems Computer Corp**, Mountain View, CA. (800) 821-4643. **Circle No. 359**

Adapter links Silicon Graphics Indigo workstations to a VMEbus system. The Model 607 adapter lets either system function as bus master on the other system. The SGI Indigo workstation can directly control and communicate with VMEbus cards as though they were on the workstation's local GIO bus. The adapter provides data-transfer rates as high as 26 Mbytes/sec. The two-card set costs $2850. **Bit 3 Computer Corp**, Minneapolis, MN. (612) 881-9674. **Circle No. 360**



Video camera for scientific applications is microscope compatible. The FlexCam Scientific desktop video camera, with more than 270,000 pixels, outputs 350 TV lines of resolution. The standard C-mount lens focuses down to 1 in. An optional microscope adapter ($195) is compatible with most industrial microscopes. $995 **Videolabs Inc**, Minneapolis, MN. (612) 879-1995. **Circle No. 361**

Unix software-development tools for Novell UnixWare. The SunSoft WorkShop software-development tools for Novel UnixWare are available for C ($1495), C++ ($1995), and Fortran ($2100). All of the tool suites provide the ProCompiler C-language system for cross-language development and migration amon other programming languages. The tool suite include the ProWorks development tools for browsing debugging, analyzing, an tuning applications. **SunSoft Inc**, Mountain View CA. (800) 278-6776. **Circle No. 36**

Color X Windows terminals start at $749. The L color base without monito is $749, and the LX14C colo X terminal with 14-in. colo monitor and 1024×768 pixel resolution is $1099 The terminals are designe around the Intel i960 RIS architecture and include 4 Mbytes of RAM, Ethernet serial and parallel ports, ar IBM-style keyboard, and a mouse. The LX19C with a 19-in. color monitor and 1280×1024-pixel resolution is $2399. **Human Designed Systems Inc**, King of Prussia, PA. (610) 277-8300. **Circle No. 363**

PC-diagnostic software adds features. AMIDiag 4.5, an upgrade from version 4.0, has expanded its testing to include EISA and PCI bus systems, expanded SVGA testing, PC-speaker testing, and a virus scan. The system information includes details on hardware including EISA, PCI, PCMCIA, SCSI, and Plug-and-Play. $149. **American Megatrends Inc**, Norcross, GA. (404) 263-8181. **Circle No. 364**

26-Gbyte optical-network-backup system operates faster than tape. The Maxoptix Axxis system writes at 66 Mbytes per minute and reads at over 132 Mbytes per minute. The optical-jukebox system can restore a typical 20-Mbyte file in about 10 secs, in contrast to a tape system that requires several minutes. $13,995. **Maxoptix Corp**, San Jose, CA. (408) 954-9700 **Circle No. 365**

Check Out the Standard in Power Components

- ✓ ISO 9001 Certified
- ✓ Worldwide Agency Approvals
- ✓ Largest Selection of Input/Output Combinations in the Industry
- ✓ Over 2.5 Million Modules in the Field
- ✓ 1-800-735-6200

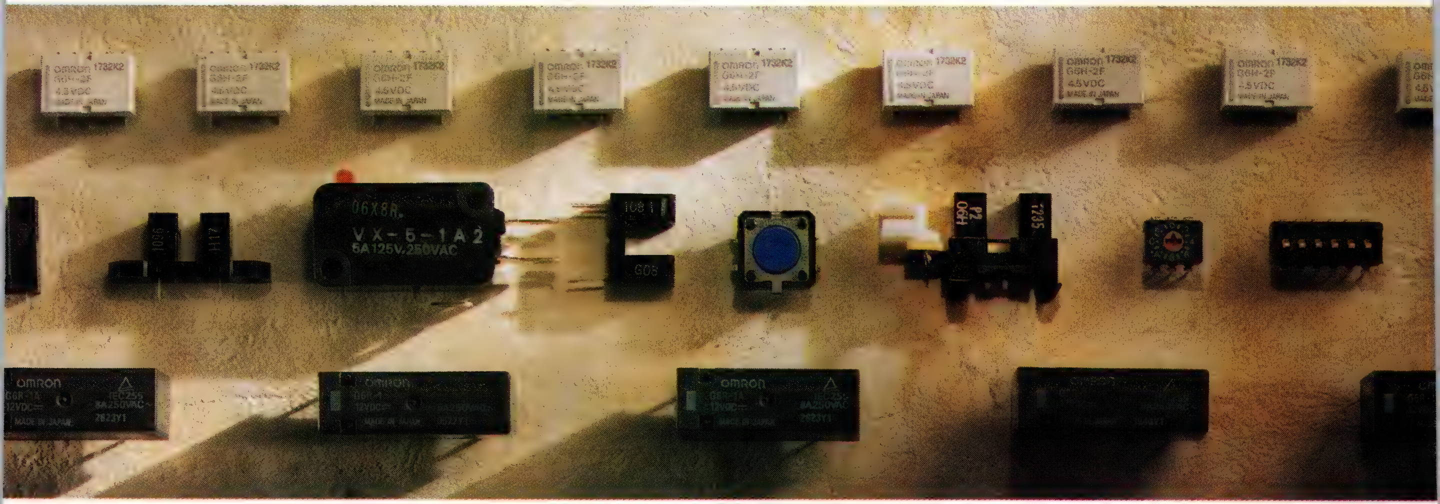
Component Solutions For Your Power System

Vicor Corporation 23 Frontage Road, Andover, MA. 01810 USA • TEL: (508) 470-2900 • FAX: (508) 475-6715
Vicor GmbH Carl-von-Linde Strasse 15 D-85748 Garching-Hochbruck, Germany • TEL: +49-89-329-2763 • FAX: +49-89-329-2767
Vicor Far East 6F- 3A, 293 - 3 FU-Hsing S. Rd. Sec. 2, Taipei, Taiwan, R.O.C. • TEL: +886-2-73643490 • FAX: +886-2-7337341

VICOR

CIRCLE NO. 137

If You Think Omron Only Makes Relay
Read Between Our Lines.



It's true we're the world's number one relay supplier. So it's not surprising to learn that design engineers and specifiers know us for our relays.

But we also manufacture the world's most complete line of switches and photomicrosensors.

For years we've been building all types of switches, photomicrosensors, and relays for leading companies that manufacture telecommunications products, home and office electronics, computer peripherals, appliances, and HVAC equipment, just to name a few.

Proven reliability makes Omron relays, switches, and photomicrosensors the preferred choice of design engineers and specifiers worldwide.

What does all this mean? That's simple. Our expertise has led to the development of standard components for all kinds of applications. And when you can fit a standard switch to your custom application, you're looking at a considerable cost savings. Plus you'll see your design go into production that much faster.

In switches alone, we have basic switches, mechanical keyswitches, rotary and in-line DIP, thumbwheel and rocker switches, amplified and non-amplified photomicrosensors, PCB mount and connector-ready photomicrosensors, as well as lighted and oil-tight pushbuttons.

And everything Omron makes is 100% tested, available to you worldwide, and backed up by outstanding technical and distribution support.

We've even set up a fax system called *ControlFax* that sends you technical data sheets through your fax machine when you dial 1-708-843-1963.

To find out if Omron has the component solution you're looking for, call now to receive our Standard Products Catalog. If you're someone who responds to innovation and more efficient ways of doing business, it's a story worth reading.

1-800-55-OMRON

ASK FOR OUR STANDARD PRODUCTS CATALOG. IT'S FREE!

OMRON®

WE HAVE THE FUTURE IN CONTROL

CIRCLE NO. 103

EDN
PRODUCT MART

This advertising is for new and current products.

Please circle Reader Service number for additional information from manufacturers.

PROTO EXPRESS

Best Value in the World
for
POLYIMIDE & FR4
1 to 5 DAY TURN
1 to 12 Layers
PRINTED CIRCUIT PROTOTYPES

2 PIECE PRICES FOR FR4 .062 Th.

LAYERS		1	2	3&4	5&6	7&8
SQUARE INCH UP TO	15	$233	$292	$639	$787	$935
	30	264	330	724	891	1059
	60	311	389	853	1049	1137
	90	358	448	980	1207	1434
	120	385	486	1044	1311	1559

- 5 PIECES x 1.34
- 10 PIECES x 1.67
- 5 DAY PRICES ABOVE
- UL LISTED

EXTRAS
- Photo Plotting
- Testing
- Gold Contacts - $50
- 25% - Below 8 Mil Hole
  - Below 15 Mil Hole
- SMOBC & LPI - $50

CAPABILITIES
- Buried & Blind Vias
- Polyimide Multilayer
- Full Body Gold
- Carbon Paste
- Tin nickel burn-in boards
- SMT-SMOBC
- Up to 22 layers
- Impedance control boards

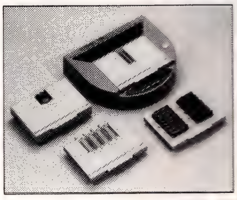
DISCOUNTS
- VISA MasterCard
  5%
- COD
  10%

FOR MORE INFORMATION CALL OR FAX

Ken Bahl ■ 1108 W. Evelyn Ave., Sunnyvale, CA 94086
Phone (408) 735-7137 FAX (408) 735-1408 Modem (408) 735-9842

CIRCLE NO. 230

UNIVERSAL/GANG PROGRAMMERS



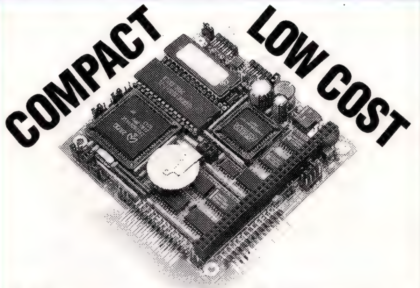
FLEX-700	
48 pin from	$945
40 pin from	$845
8 gang from	$845
TUP-400	$645
TUP-300	$495

Appreciated by over 70,000 users worldwide

- Supports Altera 7xxx, MACH 435, Xilinx, Intel FX7xxx, nearly all FPGA/CPLD/PLD...
- Support EPROM, 28/29F flash, serial PROM, PSD4XX/5XX, Intel/Motorola/NEC/Hitachi MPU devices. Over 3,000 devices supported.
- Test TTL 74/40/45 series, DRAM(SIP/SIMM), and SRAM. EPROM EMULATION option.
- Gang programming & stand alone option.
- Universal 44,68 pin PLCC modules.

Tribal
Tribal Microsystems Inc.
44388 S. GRIMMER BLVD., FREMONT, CA 94538
Tel: (510) 623-8859
Fax: (510) 623-9925

CIRCLE NO. 231



C-Programmable Controllers

Use our controller as the brains of your next control, test or data acquisition project. From $149 qty one. Features I/O to 400 lines, ADC, DAC, RS232/RS485, printer port, battery-backed clock and RAM, keypads, LCDs, enclosures and more! Our simple, yet powerful, Dynamic C™ makes programming a snap!

24-Hr AutoFAX:
916.753.0618.
Call from *your* FAX.
Request catalog 18.

1724 Picasso
Davis, CA 95616
916.757.3737
916.753.5141 FAX

Z WORLD ENGINEERING

CIRCLE NO. 232

ROM-IT
EPROM EMULATION SYSTEM

The Most Flexible EPROM Emulator You Can Get Today

- Emulates up to eight 4-Megabit EPROMS through one standard serial port.
- Downloads 2-Megabit programs in less than 23 seconds
- Examine and modify individual bytes or blocks.
- Accepts Intel Hex, Motorola S-Record and Binary files.
- Software available for IBM PC and compatibles.
- Base 27256 EPROM System **$395.00**. Other configurations available.

Incredible Technologies, Inc.
Visa, Mastercard and American Express Accepted

Order Now - It's Easy
Call (708)870-7027 Or Fax (708)870-0120
For More Information

CIRCLE NO. 233

DECISION
IS YOURS!
as to who gives you the best value?
5 Day Turn For FR4

	QUANTITY	2	5	10
SINGLE (SQ IN)	15	$186	$245	$310
	30	210	280	352
	60	248	330	415
	90	285	380	486
	120	305	415	519
DOUBLE (SQ IN)	15	$230	$310	$389
	30	264	350	441
	60	312	415	520
	90	358	475	597
	120	388	515	649
4 LAYER (SQ IN)	15	$595	$790	$950
	30	650	820	995
	60	760	925	1150
	90	834	1045	1310
	120	880	1140	1419

	QUANTITY	2	5	10
6 LAYER (SQ IN)	15	$715	$950	$1175
	30	795	1040	1350
	60	890	1190	1425
	90	995	1355	1710
	120	1048	1480	1860
8 LAYER (SQ IN)	15	$840	$1125	$1395
	30	950	1275	1595
	60	1025	1495	1875
	90	1290	1725	2150
	120	1405	1875	2325

EXTRAS
- Photoplotting
- Gold $50.00
- Testing

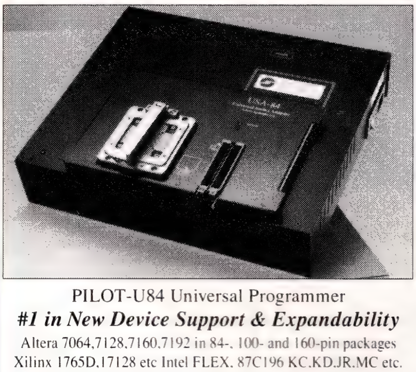
SERVICES
- Same day Prototype
- Hi-Volume Production Runs
- Instant Quotes
- Complete CAD/DFM Service
- Deep Tank Gold & Palladium
- 24 Hour Modems
- Gerber/AutoCad/HPGL/P-CAD
- SMT & Thru Hole Assembly
- Stencil

Accutrace inc.

CALL US TODAY AT
408-748-9600

CIRCLE NO. 234

Advin



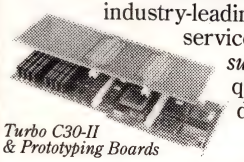
PILOT-U84 Universal Programmer
#1 in New Device Support & Expandability
Altera 7064,7128,7160,7192 in 84-, 100- and 160-pin packages
Xilinx 1765D,17128 etc Intel FLEX, 87C196 KC,KD,JR,MC etc.
Moto 68HC711, 68HC705, WSI PSD-3XX,-4XX,-5XX,PAC,SAM
Atmel 29C040, ATF22V10 etc. AMD MACH435, 29F040, etc
Lattice pLSI-1000,2000,-3000, Microchip PIC micros
All packages to 256-pin: PLCC,PGA,QFP,TQFP,TSOP,SOIC
800-627-2456 FAX:(408) 736-2503, Sunnyvale, CA.

CIRCLE NO. 235

To advertise in Product Mart, call Joanne Dorian, 212-463-6415

This DSP System will help get your new product to market fast.

Blazing-fast, PC-based Turbo C30-II Real-Time DSP Development Board gives you the *tools* (like TI TMS320C30 32-bit DSP; up to 2MB Dual Access, 0 wait state memory; 4.2MB/sec data transfer; TI & Tartan C/C++ software; and more)—and industry-leading engineering services provide *support*—for quick product design.

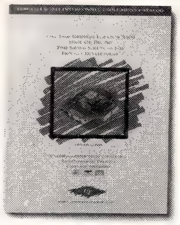


Turbo C30-II & Prototyping Boards

Call 800-550-7302 for details.

WINTRISS ENGINEERING CORPORATION

CIRCLE NO. 236



#1 in Adapter Solutions for over 10 years

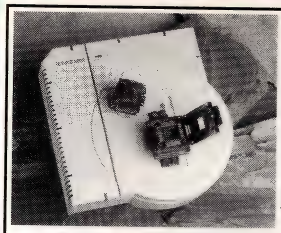
FREE 1994 Interconnect Solutions Catalog

- ✓Over 3,500 devices for one-stop-shopping
- ✓120 "Off-the-shelf" items available for overnight delivery
- ✓Unlimited application consulting
- ✓Time saving solutions for product development
- ✓Ask about our custom designs
- ✓Leading edge technology -- over 500 PQFP solutions

EMULATION TECHNOLOGY, INC.

800.995.4381

CIRCLE NO. 237



10% off all adapters ordered with programmer

PC-based Programmer for over 1800 Devices

- ✓Program CMOS, PLDs, FPGAs, bipolar and MCUs
- ✓Semiconductor manufacturer approved algorithms
- ✓Over 400 adapters available from stock
- ✓Immediate device list updates via BBS 408-982-9044
- ✓Ask about our trade-in discount offer
- ✓Same day delivery

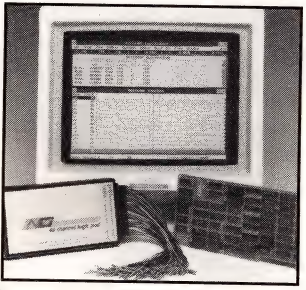
EMULATION TECHNOLOGY, INC.

800.995.4381

CIRCLE NO. 238

---

48 Channel 50MHz Logic Analyzer



Complete System $1695.00

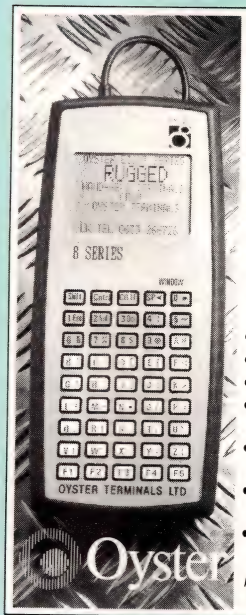
New Windows 3.1 Compatible Software

- 48 Chnnls @ 50 MHzx 4K words deep
- 16 Trigger Words/16Level Trigger Sequence
- Storage and recall of traces/setups to disk
- Disassemblers available for: 68000,8088,8086, 6801, 6811, Z80, 8085, 6502, 6809, 6303, 8031, 64180

NCI

6438 UNIVERSITY DRIVE,
HUNTSVILLE, AL 35806
(205) 837-6667 FAX (205) 837-5221

CIRCLE NO. 239



OYSTER 8 RANGE

IDEAL IN TOUGH ENVIRONMENTS

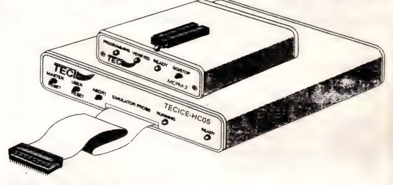
Features on the OYSTER 8 range of Hand-held terminals include:

- Xenoy casing - able to withstand a 5 ft. drop onto concrete
- Up to 512K of Ram and Rom
- EMC approved
- IP65
- Programmable in BASIC, C or Assembler
- 45 key programmable membrane keyboard
- Up to 8 lines of 20 character graphics display
- plus many more options available

714-361-2038

CIRCLE NO. 240

6805/68HC05/68HC11 DEVELOPMENT TOOLS



TECI'S Emulators are very affordable yet sport many features found only on higher priced systems. Emulators come with Cross Assemblers and Symbolic Debuggers. Our Emulators start at $895.00. Hundreds of customers tell us that the only inexpensive thing about our products is the price.Call Today for your free catalog.

Programmers, Simulators, Assemblers,Compilers, and Primer for beginners also available.

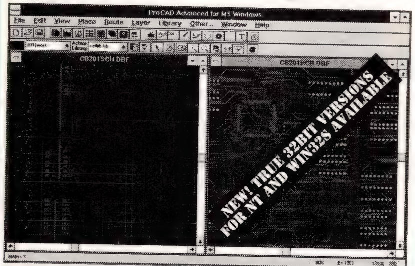
TECI

For Fast Service Call Toll Free 1-800-336-8321

The Engineers Collaborative,Inc.
RT. 3 Box 8C Barton,VT. 05822 USA
Tel: (802) 525-3458 Fax: (802) 525-3451

CIRCLE NO. 241

Windows Schematic Capture to PCB Layout Single System Dynamic Integration $995


ProCAD Advanced for MS Windows
NEW! TRUE 32BIT VERSIONS FOR NT AND WIN32S AVAILABLE

Before Spending a lot of money on 80's tech. PADS, Protel, P-CAD etc, You should take a look at our 90's Dynamic "One CAD Solution"-Schematic capture,PCB, two sided SMT,Autorouter, Mechanical drafting ...

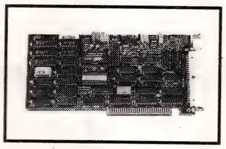
- ☑Integrated Schematic, PCB, & Mech. drafting
- ☑Real time Pin/Gate swap & Cross Probe, 1u Res.
- ☑Real time Fwd & Bkwd Annotation, Network, etc
- ☑OrCAD,PADS,PCAD,AutoCAD,Protel, etc Compt.
- ☑True 32bits, No Limits!!. Call for tradeup discount

Full function eval. kit with complete manuals (4Bks) $100.00 (Creditable towards purchase).

Interactive CAD Systems, P.O. Box 4182
Santa Clara, CA 95056. (408) 970-0852, FAX: (408) 986-0524

CIRCLE NO. 242

LOW-COST DATA ACQUISITION BOARDS



PCI-20428W. Because Your Customers Expect More for Less.

- OEM Pricing: from $249 (100's)
- 16SE/8Diff Analog Inputs, 100kHz (DMA)
- Gains (1), (1, 2, 4, 8) or (1, 10, 100)
- 2 Analog Outputs, 100kHz (DMA optional)
- 1 Counter/Timer; 2 Rate Generators
- 8 Digital Inputs, 8 Digital Outputs

(800) 685-9911
Fax: (602) 573-0522

INTELLIGENT INSTRUMENTATION™

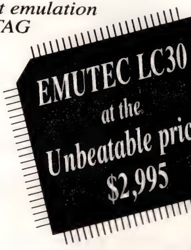
6550 S. Bay Colony Dr., MS130 • Tucson, AZ 85706

CIRCLE NO. 243

Right on Target...

EMULATOR for the TMS 320C3X at less than ½ price!

- * *Top-ranking multilevel debugger*
- * *Power-packed command set*
- * *User-friendly*
- * *Target emulation via JTAG*

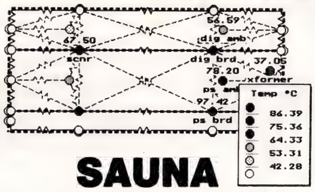


8 Shaul HaMelech Blvd.
Tel Aviv 64733, Israel.
Fax 972-3-693-8441

EMUTEC

CIRCLE NO. 244

JUNCTION TEMPERATURE!



SAUNA

a better way to deal with heat

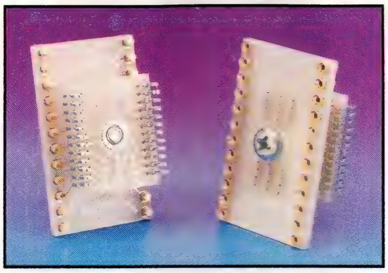
- Interactive menu-driven.
- Models: enclosures, plates, circuit boards, heat sinks.
- Analyze the whole system.
- All heat transfer modes.
- Powerful edit features.
- Thermal parameters library.
- English language design summaries.
- IBM PC & Macintosh II.

Call For Free Evaluation Kit

Tatum Labs, Inc.
1287 N. Silo Ridge Dr, Ann Arbor MI 48108 USA
313-663-8810

CIRCLE NO. 245

SOIC TO DIP



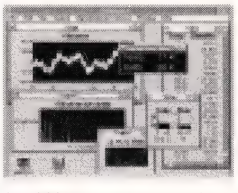
WITH DIP/SOIC PACKAGE CONVERTER

- Convert surface mounted SOIC pattern to DIP.
- Solder to SOIC Land Pattern.
- Then plug DIP IC into DIP socket.
- DIP pins are gold plated machined pins.
- Multiple sizes available

IRONWOOD ELECTRONICS
P.O. BOX 21151, ST. PAUL, MN 55121
(612) 431-7025; FAX (612) 432-8616

CIRCLE NO. 246

Intelligent Data Acquisition



DAPwindows™, the new, easy way to develop high performance data acquisition applications under Windows, lets you implement your data acquisition application on a **Data Acquisition Processor**™ board without Windows programming.

■ Every Microstar Laboratories™ Data Acquisition Processor, from the entry level DAP 800™ to the 486-based DAP 3200e™, has its own processor on board to handle the time-critical parts of an application.

■ In measuring or controlling a real-time process, computing power has to be there when it is needed. If it isn't, readings are lost and results are corrupted. With a DAP, an application has the computing power it needs when it needs it — free from the multitasking delays and resource demands of Windows. And with DAPwindows there's no Windows programming.

Call us about your project; ask for a FREE demo diskette.
206-453-2345 / fax 206-453-3199

MICROSTAR LABORATORIES™
2265 116th Avenue NE, Bellevue, WA 98004

CIRCLE NO. 247

Simple, personal device programming

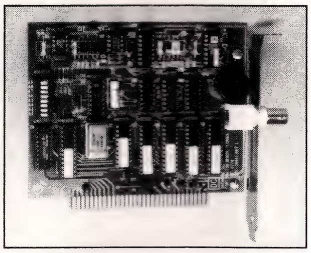
- **ChipLab**™ makes device selection and programming fast and easy with its Windows™-like user interface
- Extensive on-line help
- Programs more than 2000 PLDs, PROMs, EPROMs, EEPROMs, and MCUs
- $895 (32-pin version) or $1495 (48-pin version)

To order call:
Authorized Distributors
JDR Microdevices 1-800-538-5000
Promark Technology West 1-800-227-3345
or call:
Data I/O Corporation 1-800-332-8246 Ext. 901

DATA I/O

CIRCLE NO. 248

DO YOU HAVE THE RIGHT TIME?



- Synchronize your PC Clock to an IRIG Time Standard
- Lowest Cost, Half-Length Model 8386 Time Decoder Board
- DOS Executable and Source Interface Software included
- Custom and Special Requirements Supported

FOR PRICE AND DELIVERY CALL (904) 244-6121
or FAX Your Requirements to: (904) 244-6344

DATACOM, INC.
651 Anchors St., Fort Walton Beach, Florida 32548

CIRCLE NO. 249

MetaLink Corporation

Melts the Price of 8051 ICE

iceMASTER-PE In-Circuit Emulators from $851

New AET (patented) emulator architecture delivers incredible value!

- Up to 42 MHz Operation
- 128K Code/XDATA Memory
- 128K Hardware Breakpoints
- Optional 16K Transparent Trace (View Trace While Executing)
- Real Time & Nonintrusive
- Symbolic & Source-Level Debug
- Windowed User Interface
- Serial Link to Any PC
- 8031/8032/8X51/8X52
- 8XC51FX/87L51FB
- 8XC751/752
- DS80C320

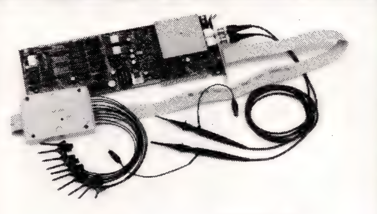
Call today for FREE DEMO DISK!

(800) 638-2423

MetaLink Corporation
Phone: (602) 926-0797 FAX: (602) 926-1198

CIRCLE NO. 250

200Ms Digital Oscilloscope



Starting at $1799 With Probes & Software

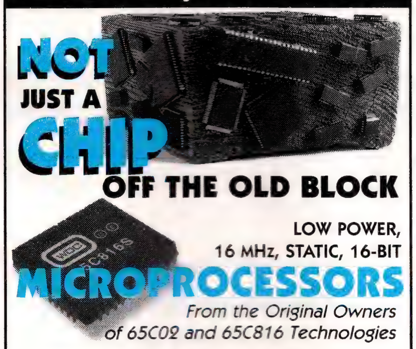
- 200 MSa/s Sampling Rate
- up to 128K Samples/Channel
- PC-BASED INSTRUMENT
- 2 Analog Channels (2ch. Oscilloscope)
- 8 Digital Channels (8ch. Logic Analyzer)
- 125 MHz Single Shot Bandwidth

Call (201) 808-8990

Link Instruments
369 Passaic Ave, #100, Fairfield, NJ 07004 fax: 808-8786

CIRCLE NO. 251

65C02S, 65C816S



NOT JUST A CHIP OFF THE OLD BLOCK

LOW POWER, 16 MHz, STATIC, 16-BIT

MICROPROCESSORS

From the Original Owners of 65C02 and 65C816 Technologies

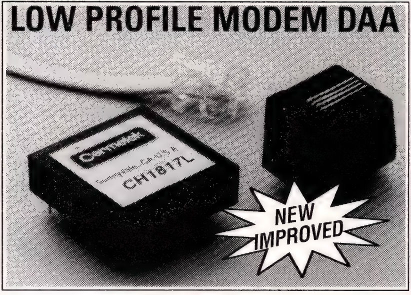
The Western Design Center, Inc.
2166 East Brown Road
Mesa, Arizona 85213
602-962-4545
602-835-6442 (FAX)
Core Licenses available

WDC

65C134S, 65C265S

CIRCLE NO. 252

LOW PROFILE MODEM DAA



CH1817L

- Low Power
- AC Noise Filter
- Caller I.D. Option
- 0.3" H x 1.0" x 1.0"
- UL 1459 Approved
- FCC Part 68 and DOC Approvable
- Compatible with all modem & Fax chip sets, including V.32

Your Source for Modem Components

Cermetek microelectronics

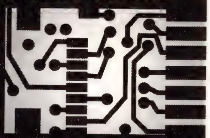
Tel: 408-752-5000
Fax: 408-752-5004

Cermetek Microelectronics, Inc.
1308 Borregas Ave. • Sunnyvale, CA 94089

CIRCLE NO. 253

the prototype specialists.

FR-4 **24** Hour Turn Available
FLEX
RIGID FLEX
TEFLON
POLYIMIDE

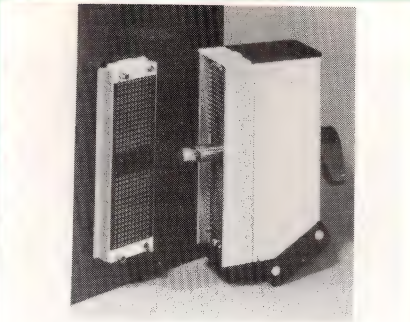


No Board is Too Difficult!

Since 1980 **CIREXX CORPORATION**

Call for a Quote
(408) 988-3980

CIRCLE NO. 254



Quick Disconnect Cable Connector

N Series connectors include 1/2 turn jacking for rapid coupling & disconnect. Hypertac© low insertion force pin & socket contacts provide wiping action needed for dry circuit to 3 amp use. Models with 60 through 300 contacts are available with crimp, printed circuit board, solder cup, and Wire Wrap© contacts.

FOR ADDITIONAL INFORMATION, CONTACT:
HYPERTRONICS CORPORATION
16 Brent Drive, Hudson, Massachusetts 01749
(800) 225-9228 or (508) 568-0451
FAX: (508) 568-0680

CIRCLE NO. 255

NEW!

Softools, Inc. is the single source for Z80 & Z180/HD64180 *low-cost* development tools including ANSI C cross compilers, macro-assemblers, realtime kernels, and now introducing the lowest-cost, full-featured, non-intrusive in-circuit emulator available.

Do it right!
Z180 Complete Solution

Up to 20Mhz, 0 wait state emulation • Up to 115k baud serial downloads - 105k in 10s • 128k to 1MB write-protectable overlay RAM • 1 MB execute, memory read/write, I/O write breakpoints • 1 MB address monitor, breaks on any combination of execute, read or write from address. • Debug without hardware • *Includes:* High-powered Turbo-debug-like source-level debugger • Debug assembly and C code • Open multiple windows • Watch/inspect/modify any C variable of any type • Structs and arrays expand into members and elements • Banked program support • Unlimited program size • Full mouse support • Runs under Windows 3.1 • Seamless support for Softools' Control Cross-C and others • *Do it right* - fix your bugs fast!

Z180 ICE-CUBE INTRO PRICE FROM $1799

Also available -- ANSI C compilers, macro cross-assemblers and real-time OS packages for the 8085, Z80, Z180, Z280, and TLCS-90.

410-964-9903 Sales
410-964-9905 FAX/BBS

© 1994, Softools, Inc. All trademarks owned by their respective companies.

CIRCLE NO. 256

PCB PROTOTYPE MANUFACTURING

Sun Circuits INCORPORATED
The Right Stuff.

- 24 hour multi/rigid.
- 10 day std. delivery.
- PCMCIA & SMT.
- Blind & buried vias.
- Laser plotting.
- LPI/DFSM.
- Mil GF & GI.
- Courteous staff.

Call: (800) **PCB-RUSH®**
SERVICE
(800) 722-7874

5124 Calle del Sol • Santa Clara, CA 95054
(408) 727-7784 • Fax (408) 727-0347
BBS/Modem (408) 988-3591

CIRCLE NO. 257

---

24 DIGITAL I/O PCMCIA CARD

Quatech's IOP-241 is a PCMCIA card which allows parallel communication between personal computers with PCMCIA sockets and external devices. The IOP-241 is 2.1 compliant and plugs into Type II PCMCIA sockets and provides up to 24 digital input and output signals.

QUATECH ***For more information and a free catalog call 800-553-1170***
662 Wolf Ledges Parkway, Akron, Ohio 44311 FAX: (216) 434-1409 BBS: (216) 434-2481

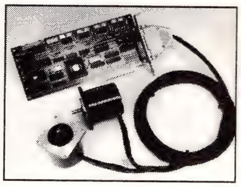
CIRCLE NO. 258

Easy Stepper Automation

Use a PC to automate your machine.

Presenting the **AGL4**:

- **2 Stepper motor drivers**
- **8 high power outputs**
- **26 switch/sensor inputs**
- **8 TTL outputs**



All in one PC expansion slot!

Simply plug the card into your PC and bolt the stepper motors to your drive shafts. Then you can:

- Move the motors using the PC keyboard or mouse.
- Use our libraries to give your program immediate control.
- Or put together a simple machine automation sequence using our friendly "IF-THEN-MACHINE" software.

California Robotics
5437 Scotts Valley Dr. #C Scotts Valley, CA 95066
Phone: 408-438-6810 Fax: 408-438-6748

CIRCLE NO. 259

A Complete Line of Development Boards, Programmers and In-Circuit Emulators

NEW…NEW…NEW…NEW…

DS-186 – In-Circuit Emulator for 80C186/8/XL/EA/EB/EC, V40/50 8086/8 and other µCs

***** *NEW ADDRESS IN THE USA* *****

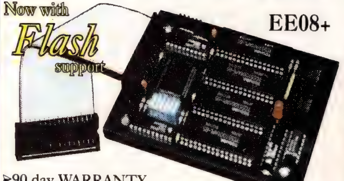
Call today for your free demo and software update

Toll Free: 1-800-833-4084

CEIBO
7 EDGESTONE CT.
FLORISSANT, MO 63033
TEL: 314-830-4084
FAX: 314-830-4083

CIRCLE NO. 260

FLEXIBLE
Memory EMULATORS



- ➢90 day WARRANTY.
- ➢10 day MONEY-BACK GUARANTEE.
- ➢Supports Read and WRITE access by TARGET.
- ➢Download and VERIFY from HOST.
- ➢View/Edit SRAM contents while target is running.
- ➢Full screen ASCII/HEX editor included.
- ➢Libraries provide high level access to emulator.
- ➢Daisy-chain up to 4 units for multi-EPROM targets.
- ➢Field upgradable to 4Mbit (27040) emulation.
- ➢Battery back-up, PLCC and 16bit adapters available.

TechTools
(214) 272-9392
FAX: 494-5814

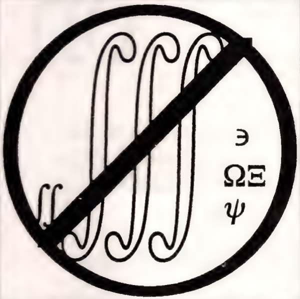
Models start at $129

CIRCLE NO. 265

DSP

Without Tears™

Learn DSP and put your knowledge to work IMMEDIATELY!



COMING TO A CITY NEAR YOU

Atlanta
Denver San Jose
Scottsdale, AZ
Long Beach, CA
Ft. Lauderdale, FL

Call Z Domain Technologies, Inc.
800-967-5034
404-587-4812

Hours 9-5 EST.
Ask for a brochure.

Our 2-Day Advanced Course is ready. Call for more info.

By taking this 3-Day Course you will really learn DSP. Guaranteed!

IOWA MIDWEST

RF/TELECOM **WIRELESS**

NEBRASKA-MINNESOTA-ILLINOIS

I have immediate openings for Design Engineers and Technical Project Managers with BS/MS plus 3 to 10 years RF/Radio design experience in any of the following areas: RF circuit design (100 MHz to 3.0 GHz), Receivers, Transmitter Exciters, Low-noise Frequency Synthesizers, Power Amplifiers, Spread Spectrum Modulation, Digital Radio DSP. These positions are all with top non-defense companies in good Upper-Midwest locations

DON GALLAGHER, MSEE
Gallagher & Brei Associates
1145 Linn Ridge Rd., Mount Vernon, IA 52314
(319) 895-8042 • Fax (319) 895-6455

PROFESSIONAL SERVICES

PRODUCT ENGINEERING & MFG., INC.

Over 25 Years Experience in Complete Mechanical Services

- **Industrial Design & Rendering**
- **Enclosure Design**
- **Mechanism Design**
- **Reverse Engineering**
- **Product Evaluation**
- **Prototyping**

From hand held Plastic Products...
.........Too Complete Machines

CALL FOR BROCHURE
Virginia 1-800-848-2553

GREAT *IDEAS* AT *WORK*

If you want to create technology that will determine the speed and direction of this industry, you can do it here. Be a part of the push to invent and innovate. Work to discover your own potential, in an environment that merges diverse skills, backgrounds and experience together into a common course: To be the Number One computer company by 1996.

Because there's a place for the dreamers that do, and the doers that dream. That place is right here, at Compaq.

COMPONENT TEST ENGINEERS

In these positions, you will need a minimum 2 years' ATE component level Memory test experience (DRAMs, VRAMs, SRAMs, Flash EEPROMS); a BSEE/ET or equivalent; as well as strong verbal/written and leadership skills. Expertise in the use of lab equipment such as oscilloscopes is helpful, as is Advantest and Teradyne experience. The ability to work independently in a team environment is key.

Compaq offers competitive salaries, comprehensive benefits and an environment that supports creativity, open communication and team involvement. To find out more about joining the Compaq team, submit your resume and salary history to: Compaq Computer Corporation, Dept. CLMO-EDN-1027-CTE, MC 050207, P.O. Box 692000, Houston, TX 77269-2000, Fax 713-378-9197. An equal opportunity employer m/f/d/v.

COMPAQ

Quality design and advanced technology. Because lives depend on it.

Siemens Pacesetter is a world leader in technological innovation for cardiac arrhythmia management devices. Together with our parent company, multibillion dollar Siemens, we are bringing these life-saving and life-enhancing products to today's everchanging healthcare marketplace. If your vision matches ours, we offer a supportive, advancement-oriented environment to the professionals who join us as:

SR. SOFTWARE ENGINEER (Software Development Dept.)

Individual will use creativity and high-quality standards to design and implement software for implantable/external pacemaker applications. Responsibilities include developing product and software specifications, architecture design, detailed design, implementation, unit tests and integration tests suite. 5+ years experience in all phases of high reliability software development is required. BSCS/MSCS and C/C++ background preferred. Demonstrated systems development experience using OOP techniques in real-time systems desirable. **Respond to Dept. EDN/SSE.**

SR. STAFF SOFTWARE ENGINEER Advanced Product Development

Will design/develop software for new pacemaker/programmer interfacing and communications. Involves requirements definition, design, coding, testing and debugging. Will also perform large scale software integration to ensure functionality of final product. Requires a BS/MS degree in CS or equivalent and 5+ years experience with knowledge of Assembly and C. **Respond to Dept. EDN/SSSE.**

SR. MECHANICAL DEVELOPMENT ENGINEER

The selected candidate will be called on to design and develop new leads, as well as provide test protocols and documentation. Also entails coordinating leads project teams, and designing related tooling/fixtures. Related BS degree in Engineering required, with 5+ years directly related experience. **Respond to Dept. EDN/SMDE.**

TEST ENGINEER

Our selected candidate will develop and design new software/hardware to test new products, maintain existing software and test equipment, and generate related documentation and reports. BSEE or equivalent and a minimum of 5 years mixed signal test engineering experience strongly preferred. Knowledge of C program language (with a preference in Assembly) and precision analog test methods/circuits a must. **Respond to Dept. EDN/ATE.**

In addition to our desirable Southern California location, we offer competitive compensation, paid relocation and complete benefits, including 401(k) savings, tuition reimbursement, vision care and a choice of medical/dental plans. Send resume (NO PHONE CALLS, PLEASE!) to the appropriate department: **Sue Mayes, Employment Representative, Siemens Pacesetter, Inc., 15900 Valley View Court, P.O. Box 9221, Sylmar, CA 91392-9221.** AA/EOE.

Siemens Pacesetter

Excellence in Cardiac Pacing

EDN INTERNATIONAL ADVERTISERS INDEX

Company	Page	Circle
3M Components	142	2
AMP	119	3
Accutrace	149	234
Actel Corp	47	148
Adastra Systems	122	110
Advanced Micro Devices Inc	12-13	
	30-31	
Advin Systems	149	235
Allegro Micro Systems	62	144-147
Allied Electronics	113	92
Analog Devices Inc	19	93
	159	109
Applied Micro Circuits Corp	141	91
Benchmarq Microelectronics Inc	100	4
Burr-Brown Corp	21	111-115
	93	154
CEIBO	152	260
California Robotics	152	259
Capital Equipment Corp	130	138
Cermetek Microelectronics Inc	151	253
Cirexx	152	254
Compunetics Inc	94	19
Condor D.C. Power Supplies	C2	26
Crystal Semiconductor	34	27
Cypress Semiconductor	11	
Data I/O Corp	151	248
Data Translation Inc	59	28
Datacom Inc	151	249
Datel Inc	98-99	203-211
Digi-Key Corp	1	29
Digital Equipment	121, 123	
EDI Corp	135	33
ESL Inc	60	30
Eagle-Picher Industries Inc	144	31
Ecliptek Corp	128	32
Elanix Inc	127	94
Emulation Technology	150	237-238
Emutec	150	244
GE Rental/Lease	57	34
Hamilton Hallmark	50-51	121
Heurikon Corp	91	36
Hypertronics Corp	152	255
Hyundai Electronics Industries	114-115	95
IBM Microelectronics-Embedded Systems	134	37
IEE	145	117-118
Incredible Technology	149	233
Information Handling Services	156	38
Integrated Device Technology Inc	79	96
Intelligent Instrumentation	131	39
	150	243
Interactive Cad Systems	150	242
International Rectifier	C3	46
Ironwood Electronics Inc	151	246
LeCroy Corp	14	47
Linear Technology Corp	82	48
	95-96	
Link Instruments	151	251
MSI	81	149
MATRA MHS/TEMIC	32	139
Maxim Integrated Products	87	155
	89	153
Metalink Corp	151	250

Company	Page	Circle
MicroSim Corp	17	150-152
Microstar Labs	151	247
Microware Systems Corp	137	97
Mini-Circuits	3	49
	85	64
	160	156
Motorola Semiconductor Products Inc	43	
NCI Corp	150	239
NCR Corp	28	65
NEC Crop	52-53	66
National Semiconductor	67-68	
Nohau Corp	138	69
NordicTrack	143	123
Omron Electronics	148	103
Oyster Terminals	150	240
Paradigm Technology Inc	45	124
Pearson Electronics	122	76
Pentek Inc	139	77
Philips Semiconductors	36-37	158
	80	78
	109-112	
Pico Electronics	140	79
	155	79
Piher International Corp	143	80
Power Trends	65	81
Quality Semiconductor Inc	61	82
Quatech	152	258
Quicklogic	116	104
Ross Technology	33, 35	125
Samsung Semiconductor Inc	124-125	105
Siemens Components Inc	23	106
Sierra Circuits	149	230
Signal Transformer Co	C4	83
Silicon Systems	129	84
Siliconix a Member of TEMIC Group	2, 8-9	
Softools	152	256
Sony Semiconductor	24-25	85
Sun Circuits	152	257
TECI	150	241
Tech Tools	152	265
TEMIC	32	139
Tartan Inc	105	86
Tatum Labs	151	245
Tektronix Inc	133	87
Texas Instruments	6-7	88
Toshiba America Electronic Components	26-27	98-99
Tribal Mircosystems	149	231
Unitrode Integrated Circuits	54	107
Vicor Corp	97	136
	147	137
Welch Allyn	94	108
Western Design Center	151	252
WinSystems	126	157
Wintriss Engineering	150	236
Zworld Engineering	149	232

Recruitment Advertising 153

*Advertiser in European edition

This index is provided as an additional service. The publisher does not assume any liability for errors or omissions.

PICO

SURFACE MOUNT DC-DC Converters

3.3 to 1000 VDC Output Standard

ACTUAL SIZE

PICO's SM and SMV Series
- 1.25 watt output at 70° ambient
- 140 standard models
- Ultra-miniature size .34 ht., 3.5 grams weight
- 5 input voltage ranges 5, 12, 24, 28 and 48 VDC
- Up to 1500 volts input/output isolation
- No heat sink or electrical derating required
- Up to 1000 volts DC output
- MIL-STD 883 options available
  - Expanded operating temp (–55°C to +85°C)
  - Stabilization Bake (125°C ambient)
  - Temperature Cycle (–55°C to +125°C)
  - Hi Temp, burn in
- Over 1400 standard DC-DC and AC-DC models up to 200 watts

Delivery— stock to one week

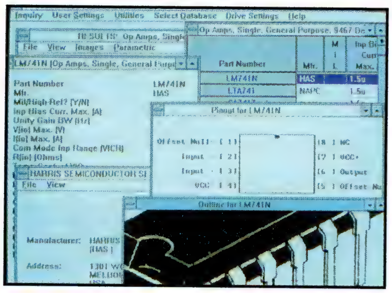
See EEM
or send direct
for **Free** PICO Catalog.
Call toll free **800-431-1064**
in NY call **914-699-5514**
FAX **914-699-5565**

PICO Electronics, Inc.
453 N. MacQuesten Pkwy., Mt. Vernon, N.Y. 10552

CIRCLE NO. 79

Introducing CAPSXpert® The best of two component databases combined into one Windows™ tool.

Some of the finest things in life result from ideal combinations. When IHS® wanted to create the world's most powerful component selection tool, we combined the strengths of CAPS and IC/Discrete with the functionality of Windows to bring you the ultimate — CAPS*Xpert*.


Inquiry User Settings Utilities Select Database Drive Settings Help
File View Images Parametric
Part Number
Mfr.
HARRIS SEMICONDUCTOR
Pinout for LM741N
Outline for LM741N
Manufacturer:
Address:

CAPS*Xpert* will revolutionize the way you search and compare components. CAPS*Xpert* gives you:

- More data • Unbeatable currency
- User-defined upgrade and downgrade criteria • Graphical pinout and package displays • Distributor and sales office listings.

Innovative search commands and multiple window capabilities make finding the current information your engineering team needs faster and easier than ever before. CAPS*Xpert* is the tool you need to reduce redesign costs, avoid expensive product delays, and meet critical design cycles.

For the ultimate solution to faster, easier component selection, upgrade to CAPS*Xpert* today! Call 1-800-241-7824 or 303-790-0600, ext. 59.

IHS®

CAPSXpert. Nobody Puts It Together Like IHS.®

Available in Windows for PCs and network configurations. Call for UNIX update.

CIRCLE NO. 38

JACK GANSSLE,
EMBEDDED-SYSTEMS
CONTRIBUTING EDITOR

The organized bench

There he sits, the engineering guru of the organization, perhaps respected, but feared by all because of his arcane knowledge. His desk is a foot deep in paper, and the lab bench is a mess of old food containers and smoldering solder drippings. Tools and resistor clippings threaten to short out any test system carelessly placed on the bench. Wires crisscross every square inch of tabletop—scope probes, clip leads, RS-232C cables—all going somewhere, though perhaps no one really knows their destination.

Ask the guru for a piece of paper, and he burrows frantically through the mess. Usually the paper never comes to light because it's lost. Don't worry, he can re-create it for you as soon as he has a chance. The PAL equations that he comes up with are probably right. But if they're not, no problem: He's already debugged that circuit twice and is quite the expert.

I'm a reformed lab pig. My 12-step recovery program involved living in tiny places—a VW microbus and many boats—and forced me to become organized to deal with the lack of space. Fortunately, my personal quest for organization spread into the lab when I discovered how much time I saved by putting things away.

How many times have you seen engineering changes that never made it into production because someone forgot to write them down?

Quite simply: Mess and clutter decrease productivity. Those few minutes a day spent putting things away save hours of searching. Sweep the solder drippings off the bench occasionally, and your incidence of catastrophic failures can plunge dramatically.

An organized lab promotes correctness. How many times have you seen engineering changes that never made it into production because someone forgot to write them down? Or, the notation was made on the corner of a napkin that was accidentally used to wipe up a spill.

When starting to debug a new project, remove everything from the bench and sweep it. A quick wipe with a damp cloth removes those accumulated coffee stains. Then, put everything not absolutely needed back on the shelves. This is your chance to remove the clutter, so be relentless.

Be sure you can easily reach the computer's frequently used connectors. If two devices must share an RS-232C port, buy a switch box ($10 from Jameco at (800) 831-4242) and reduce the wear and tear on connectors—and your back.

Don't work with unacceptable power distributions. Too many of us spend half our lives swapping power plugs, so you should consider buying an outlet strip (Techni-Tool (215) 941-2400) sells strips of 15 for $64).

Many years ago, Miles and Beryl Smeaton sailed their aging boat around Cape Horn with expert boat builder John Guzzwell as crew. When the boat flipped in 30-ft seas and the hull cracked open, Guzzwell was shocked to discover that all of the Smeaton's tools were rusty and dull. As water poured in, he carefully sharpened and cleaned the tools before undertaking the repairs that eventually saved their lives.

The moral is to buy good tools and take care of them. You can live with those dikes and needle-nose pliers for weeks on end. Buy cheap stuff and watch your blood pressure skyrocket every time you are unable to clip a lead close to the board. Keep your tools organized—buy a little toolbox to keep them from falling on the floor and getting lost.

How is your soldering equipment? A vacuum desolderer is great for making large-scale changes. However, during prototyping I find it's often easier to hack away at the board, mounting chips on top of chips and using plenty of blue wire.

During the first days (or weeks) of bringing up a new embedded system, I often find myself making lots of little modifications to the system. A hot iron always at hand is critical. After things begin to work, I start testing I/O interfaces by writing low-level drivers and exercising the code, making software and hardware changes as needed in parallel. The code changes much faster than the wiring, so it seems wasteful to keep an iron hot all the time. (JDR (800) 538-5005) sells a neat $30 cordless-soldering iron that heats in seconds, ideal for those infrequent changes.)

Being an immensely stupid person, I

PHOTOGRAPHY / HOWARD DAVIS

require vast quantities of clip leads. Most of my ideas are wrong, so I save a tremendous amount of time by using a clip lead to try a design change and see what happens.

Clip leads have a short lifetime in a development lab. Accidentally connect V_{CC} to ground, and the plastic tip melts horribly. I hate it when that happens. We used to send a runner to Radio Shack occasionally to replenish our supply, but we found that "the Shack" couldn't keep up with our needs.

We now occasionally buy 100 clips and have a high-school kid solder up 50 leads. It gives us an infinite supply for a time, and may help a fledgling engineer find his true vocation. (Bring a part-time worker in from your local high school to help maintain the lab. The cost is minuscule, the lab is better off for it, and you show one more kid an alternative to slinging burgers.)

Beware of clip leads in high-frequency applications. Connecting a switching signal to ground with even a short lead often doesn't work. The lead looks like a transmission line and presents a rather high impedance at the frequency of your circuit—so high that it may not have an effect.

An embedded system's hardware is never far from the software. At the very least, the person responsible for designing the hardware should provide low-level software drivers to the software team. It's unfair for a person to dump a barely documented complex system onto a firmware engineer's desk and say, "Now it's your problem."

Make sure your lab area is set up for serious software development! Clearly, your computer must include the properly installed compilers and assemblers needed for the project. The debuggers, make utilities, and other software resources are as important as quality hand tools to quickly and painlessly write, compile, and test the code.

Set up the environment with a make utility so you can compile or assemble without twiddling compiler switches. Only amateurs develop by tediously hand-assembling instructions into the debugger. You should never make patches in the debugger and upload these to a file for later use. Change a source file, so you can alter the comments as required to write drivers that are beautiful to behold and a joy to use.

Develop your code with the environment the firmware folks use so they can immediately integrate your test routines. It drives me crazy to see the lousy planning so endemic in this industry. Too often laziness or stupidity reigns, so one engineer does his work under a particularly obsolete version of a compiler. Meanwhile, the rest of the team must painfully massage the code into something compatible with the version they use. Why work so hard?

Hardware design requires as much software support as does the firmware. PALs, PLDs, and FPGAs let you create much of the hardware design late in the game. Make sure your bench is set up with all of the tools you need to edit and compile these devices.

Unfortunately, too many of the tools are not happy running under a standard DOS or Windows environment. You may need a special boot sequence to free memory. Our PAL compiler isn't very happy with Microsoft's EMM386 for some reason, our PC layout software won't run from a Windows DOS shell, and the FPGA compiler requires every resource each system has—and then some. One solution is to use a boot scheme that asks the software you'll be running and then invokes the proper AUTOEXEC.BAT and CONFIG.SYS. Another strategy is to wait for all of this stuff to be reasonably available under Windows.

Often, I speak with a sad engineer trying to debug a complex system with a 286 running Windows in 1 Mbyte of RAM. Decent computers are so cheap, and modern tools demand so many resources that it's simply false economy to make do with yesterday's technology. Yet, no company can toss out all of the computers every year to follow the latest offering. Clearly, the minimum engineering machine today is a 486 with 8 Mbytes of RAM and plenty of disk space.

If you are saddled with an antique machine, measure the time spent waiting for compiles. Make a persuasive argument to the boss based on your salary plus overhead. Let him know just how much money he'll save with a $2000 to $3000 investment.

In one of my previous columns in *EDN*, I wrote about setting up a drawing system. The drawing system is only as good as the information that goes into it. All too often, the frenetic pace of debugging hardware tempts us to be less than careful about writing down changes.

Resist this temptation. Your company is paying you to debug a prototype for one reason only: so the prototype can be turned into a working production system. If you carelessly forget to document modifications, the company will need at least one additional pc-board revision, which you'll have to debug all over again. This is a terrible waste of money. A wise manager of such a documentation-free engineer either retrains or fires the individual.

Avoid scraps of paper to list things you've learned. The best solution is a meticulously maintained engineering notebook. Write everything down, clearly and concisely. The good sisters of my grammar school practically committed suicide over their failed attempts to teach me penmanship. So, writing clearly is a particular headache for me. I've learned to slow down and print because, most of the time, I can't read my own script.

Use *one* set of schematics to record changes. This is your master-development drawing set. Staple the schematics together and clearly label them as your masters.

In the movie "Jurassic Park," one brilliant slob controls a sea of workstations. When he disappears in his quest for the big score, we see his desk covered with papers and books scattered helter-skelter, old food remnants decomposing into new forms of life, and McDonald's wrappers blocking computer ventilation ports. Despite a nervous laugh, why is this image such an accepted icon of our industry?

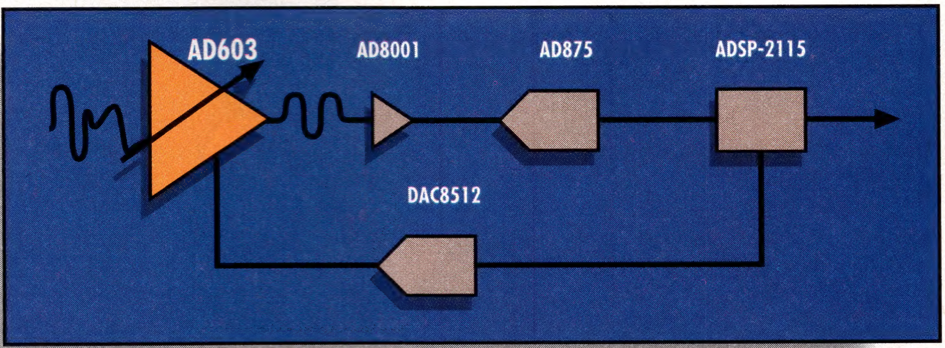
Jack Ganssle is the president of Softaid, a vendor of emulators and other embedded-systems tools. His idea of heaven is sailing across oceans, although the ugly face of common sense precludes these dreams too often. He can be contacted via Compuserve at 76366,3333,or via Internet at 76366.3333@compuserve.com. For those users of the Pony Express send mail c/o Softaid, 8310 Guilford Rd, Columbia, MD 21046.

VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

High Interest	Medium Interest	Low Interest
586	587	588

New Class Of Variable Gain Amplifiers Offer Wideband Gain Control.



Analog Devices has taken every criteria for variable gain amplifiers and made them a generation better. Greater gain accuracy. Less noise. Linear-in-dB control. Lower solution cost. The high integration of our variable gain amplifiers provides a complete, easy to use solution: simply connect the power, input and gain control voltage and you're in control.

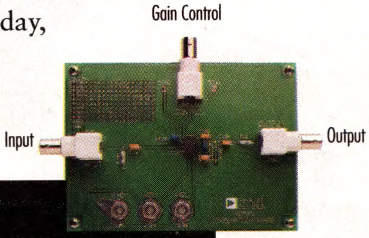
SPECIFICATION	AD600	AD602	AD603
Channels	Dual	Dual	Single
Gain Range*	0 dB to +40 dB or 0 dB to +80 dB cascaded	-10 dB to +30 dB or -20 dB to +60 dB cascaded	-10 dB to +30 dB through +10 dB to +50 dB
Input Noise Spectral Density	1.4 nV/√Hz	1.4 nV/√Hz	1.3 nV/√Hz
Signal Gain Accuracy (typ)	±0.25 dB	± 0.25 dB	±0.4 dB
Bandwidth (MHz)	35	35	90
Price/amp**	6.00	6.00	3.95

LOWER NOISE, HIGHER PERFORMANCE, BETTER VALUE THAN ALL OTHER VOLTAGE CONTROL AMPLIFIERS

AD600, AD602. For applications that demand high accuracy and integration, our dual channel AD600 and AD602 variable gain amplifiers provide an optimum solution. They're ideally suited for demanding medical ultrasound, non-destructive ultrasonic testing, and RF applications.

AD603. Our new variable gain amplifier is a high speed, low cost solution, with solid performance. The AD603 features a single channel, programmable 40 dB gain range that's ideal for cost and performance driven applications such as video, instrumentation, sonar, RF and IF AGC applications.

For a data sheet and more information on AD603 samples and evaluation board, call Analog Devices toll free today, at 1-800-ANALOGD (262-5643)†. Or fax your request to 617-821-4273.



SPECIAL EVALUATION BOARD OFFER!
Call 1-800-ANALOGD (262-5643)

ANALOG DEVICES
Analog. Digital. Solutions.

Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106.
Distribution, offices and application support available worldwide.

---

* AD603 is gain range pin programmable
** USD 1000s, recommended resale, FOB USA.

† Outside U.S., please call 617-461-3392.

CIRCLE NO. 109

2.5KHz-8GHz AMPLIFIERS

(3 Piece Set)

WOW!

only $1095 (Set of 3 1-9 qty.)

+20dBm Power Output, 20dB Gain

Model :	Freq. (MHz)	Gain (dB)	Power Output, dBm @ 1dB Compression	DC Power Volt V	DC Power Current mA	Conn. Type	Indiv. Price ($) (1-9 qty.)
ZHL-6A	.0025-500	21	+23	+24	350	BNC	199
ZHL-1042J	10-4200	25	+20	+15	330	SMA	495
ZRON-8G	2000-8000	20	+20	+15	310	SMA	495

Set of 3 Amplifiers # KZHL-318: $1095 (1-9 qty.)

Expand laboratory capabilities and put a full spectrum of power at your fingertips with Mini-Circuits 2.5KHz to 8GHz medium power amplifier set. Each ultra-wideband set contains three individual heat sinked RF amplifiers with at least +20dBm output and overlapping frequency response range capabilities; 2.5KHz to 500MHz, 10MHz to 4.2GHz and 2GHz to 8GHz. Applications for these amplifiers include increasing the signal levels to power meters, spectrum analyzers, frequency counters and network analyzers as well as boosting signal generator outputs.
You can buy these amplifiers individually at Mini-Circuits already low prices, or own the full spectrum set for the money saving price of only $1095 (1-9 qty.) ! To order from stock with a guarantee to ship within one week, call Mini-Circuits today !

Mini-Circuits...we're redefining what VALUE is all about!

Mini-Circuits®

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661

For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER Vol. 23 • MICROWAVES PRODUCTS DIRECTORY • EEM • MINI-CIRCUITS' 740- pg. HANDBOOK.

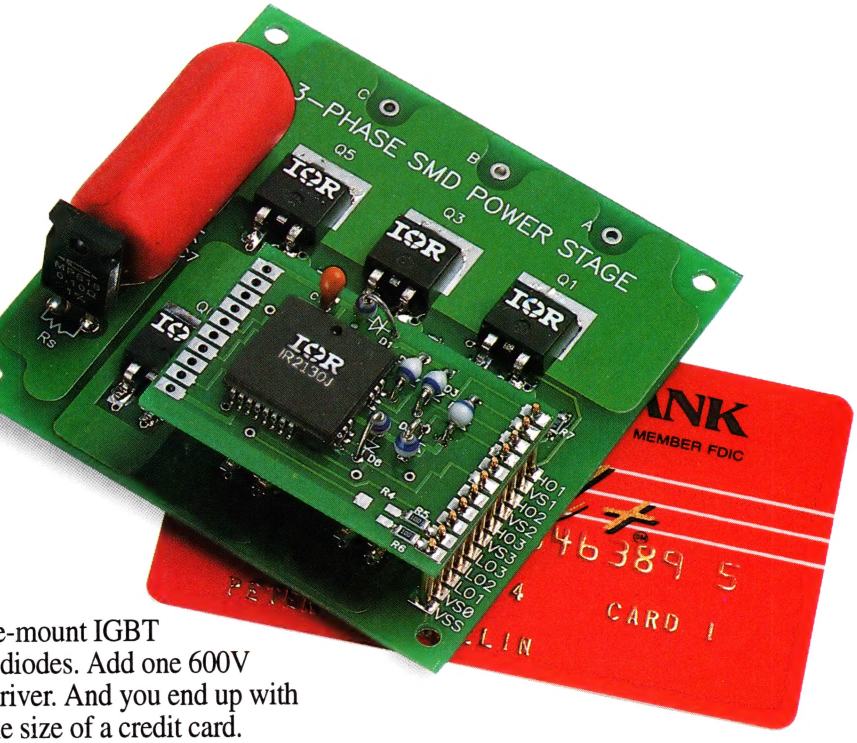
CUSTOM PRODUCT NEEDS...*Let Our Experience Work For You.*

F 176 Rev C

CIRCLE NO. 156

Power-full tiny inverter.

Or how to shrink a 1hp, 3-phase motor control inverter to fit your pocket...book.



Take six IR surface-mount IGBT *CoPacks* with built-in diodes. Add one 600V IR2130J three-phase driver. And you end up with a 1hp inverter about the size of a credit card.

The lower part count, size and weight reductions bring added value to your end product. Your customers benefit from the pass-along savings. And you gain the competitive edge.

Thanks to the most compatible line of power devices ever. Value-priced to save you money. In stock to save you delivery time. Send for our data "Shrink Pak." Quicker yet, call. 1-800-245-5549.

You'll see how small your inverters can get.

This motor control inverter is 3" x 3" sq. and features six SMD-220 surface-mount CoPack UltraFast IGBTs driven by a single 600-volt, 3-phase driver (IR2130J) with current-sensing.

Available now at key IR distributors.

IOR International Rectifier

WORLD HEADQUARTERS: 233 KANSAS ST., EL SEGUNDO, CA 90245, USA 310-322-3331, FAX 310-322-3332, TELEX 66-4464. EUROPEAN HEADQUARTERS: HURST GREEN, OXTED, SURREY RH8 9BB, ENGLAND, (0883) 713215, FAX (0883)714234

CIRCLE NO. 46

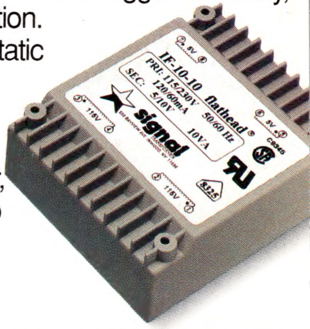
When our customers ask for a low profile transformer, we deliver.

Signal's International Flathead™-- transformers just don't come any flatter.

Talk about keeping a low profile. Signal's International Flathead transformers measure as little as 0.69 inches high...perfect for today's densely-packed circuit boards. They're UL, CSA, VDE, IEC and EN certified too.

All of the International Flatheads are fully encapsulated and hermetically sealed for rugged reliability, and feature Class B insulation. They don't require electrostatic shielding either, thanks to nonconcentric windings.

For a full-line catalog, contact Signal Transformer, Insilco Technologies Group
500 Bayview Ave.,
Inwood, NY 11096.



General Specifications, IF Series:

- **Power:** 2 VA to 30 VA
- **Dielectric Strength:** 4000VRMS Hipot
- **Primaries:** Dual primaries (115/230 V - 50/60 Hz)
- **Secondaries:** Series or parallel secondaries
- **Electrostatic Shield:** Not necessary, split bobbin construction
- **Magnetic Field:** Reduced magnetic radiation
- **Height:** .69 to 1.39 inches (17.6 to 35.3mm) high
- **Insulation:** Class B insulation (130°C)

Agency Standards:

- UL recognized to UL 506 (File #E63829)
- CSA certified to C22.2 #66 (File #LR 51265)
- VDE certified to VDE 0805 / EN 60950 (File #8325)
- VDE certified to IEC 950

International Flathead™ (IF)Series

VA (Size)	L	W	H	Wgt
2	2.09″ 53.0mm	1.73″ 44.0mm	0.69″ 17.6mm	4.6 oz 0.13 kg
4	2.09″ 53.0mm	1.73″ 44.0mm	0.77″ 19.6mm	5.4 oz 0.15 kg
6	2.09″ 53.0mm	1.73″ 44.0mm	0.89″ 22.6mm	6.9 oz. 0.20 kg
10	2.66″ 67.6mm	2.24″ 57.0mm	0.89″ 22.6mm	10.3 oz 0.29 kg
14	2.66″ 67.6mm	2.24″ 57.0mm	0.96″ 24.3mm	11.9 oz 0.34 kg
18	2.66″ 67.6mm	2.24″ 57.0mm	1.09″ 27.6mm	14.1 oz 0.40 kg
24	2.68″ 68.0mm	2.26″ 57.5mm	1.23″ 31.3mm	16.5 oz 0.47 kg
30	2.68″ 68.0mm	2.26″ 57.5mm	1.39″ 35.3mm	19.7 oz 0.58 kg

Output voltages available from 5V to 230V

Custom versions also available

BUY DIRECT: (516) 239-5777
FAX REQUIREMENTS TO: (516) 239-7208
PRONTO: 24 hr. off-the-shelf shipment

Signal Transformer

CIRCLE NO. 83